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STATE OF CALIFORNIA - THE RESOURCES AGENCY PETE WILSON, Governor

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October 1, 1997

FAX TO: Tina L. Anderholt - Imperial Irrigation District
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From Merlin B. Tostrud - Colorado River Board of California
Voice (818) 543-4676 Ex 243

Number of pages 3 Including cover

Attached are my estimates of historic flood control releases of Colorado River water from Hoover Dam. It was assumed you didn't want flood control releases prior to the formation of Lake Powell. Once Lake Powell began filling, there were no flood control releases until the year 1979. Flood control releases are based on "other" excess releases to Mexico at the Northerly International Boundary. "Other" excess releases equal measured flow at NIB minus Mexico's scheduled delivery at NIB minus delivery of Minute water. The "other" excess delivery is made up of 1) rainfall events causing runoff which cannot be controlled and must be delivered to Mexico in excess of requirements; 2) Gila River flows which cannot be used to meet the Mexican delivery requirement (due to irrigation return flows below Imperial Dam and the continual release of water from Imperial Dam's desilting basin to the river below Imperial Dam, the maximum amount of Gila River water which can be used to meet Treaty requirements is about one-million acre-feet); 3) a small amount of water delivered in excess to ensure the delivery of Mexico's water; and 4) flood control releases from Hoover Dam.

Judgement must be used to determine if rainfall or extra safety water delivery caused the excess delivery. Flood control is not an exact science. The rules which govern the amount and timing of flood control releases currently include a parameter of predicted future inflow. There is a step function of flood releases. If the required flood control release exceeds downstream demand, then "other" excess deliveries to Mexico can be expected. This assumes that users above NIB do not increase use to take advantage of the extra releases. No adjustments were made for historic uses which may or may not have been influenced by the possibility of future droughts or floods.

Bill Elder will be out of the office for two days. I shall attempt to determine the fate of your request made to him.

Calculation Of Flood Control Releases From Hoover Dam

Other Excess Arrivals At Northerly International Boundary (Acre-feet)

	1979	1980	1981	1982	1983	1984	1985	1986	1987
Jan	9, 278	209, 201	302, 140	114	585, 524	1. 520, 757	1, 328. 134	997, 389	1. 018. 855
Feb	23, 540	151, 920	15, 697	375	213, 139	1, 339, 957	1, 271, 588	729, 432	692, 676
Mar	23, 831	440. 028	18. 938	4. 191	8, 555	1. 021. 171	1, 027, 110	831, 558	330. 539
Apr	340	450, 979	1, 898	448	278, 380	865, 832	522, 478	536, 277	58, 580
May	189, 648	549, 811	117	7, 253	545, 951	984, 943	706, 605	965, 069	81, 179
Jun	161, 320	487, 070	287	7. 954	873, 544	1, 156, 061	754, 373	920, 475	48, 975
Jul	167, 189	433, 588	141	1. 907	1, 722, 338	1, 244, 973	722, 807	737, 239	30, 385
Aug	168, 128	414, 928	4, 340	5, 313	1, 855, 140	1, 107, 028	703, 475	659, 486	55, 682
Sep	174, 016	580, 717	67	1, 170	1, 757, 854	1, 075, 103	890, 868	697, 134	133, 895
Oct	204, 288	863, 164	223	720	1. 927, 177	1, 119, 031	710, 381	702, 828	184, 094
Nov	210, 027	574, 317	269	310	1, 487, 589	1, 154, 999	672, 530	603, 669	98, 857
Dec	135, 897	404, 819	355	19 563	1 344, 789	1. 283, 142	802, 175	732. 574	208. 824
Sums	1, 467, 491	5, 340, 568	342, 472	49. 318	12, 599, 960	13, 843, 017	10, 112, 324	9, 113, 729	2, 949, 341

Gila River Near Dome AZ

	1979	1980	1981	1982	1983	1984	1985	1986	1987
Jan	14, 760	136, 000	9, 310	457	153	139, 400	65, 950	2, 110	826
Feb	86, 240	88. 550	5. 860	325	87	77. 350	158. 800	3. 170	597
Mar	131, 000	195, 500	4. 540	659	18, 230	25, 460	208, 000	3. 950	731
Apr	127, 600	214, 500	2, 710	386	132, 000	9, 430	195, 300	1, 990	755
May	139, 900	222, 500	1, 270	82	148, 900	3, 900	131, 200	458	170
Jun	125, 400	159, 900	1, 640	149	155, 300	1. 530	11, 080	222	730
Jul	132, 400	98, 520	993	204	30, 120	2, 930	4, 180	280	978
Aug	144, 200	189, 100	530	1, 620	40, 750	2, 400	3, 350	332	2, 100
Sep	136, 700	200, 900	172	217	45, 550	075	2, 000	420	315
Oct	132, 900	227, 000	645	153	36, 270	811	3, 150	1, 050	494
Nov	134. 100	105. 700	371	109	137, 900	1, 010	2, 830	818	299
Dec	138, 800	18, 360	569	218	183, 100	1, 160	2, 770	893	282
Sums	1, 443, 000	1, 844, 630	20, 610	4, 779	928, 360	266, 046	789, 070	15, 696	6, 257

Calculated Flood Control Releases From Hoover Dam (Acre-feet) 1/

	1979	1980	1981	1982	1983	1984	1985	1986	1987
Jan	0	73, 231	292, 830	0	585, 371	1, 381, 367	1, 262, 184	995, 279	1, 017, 829
Feb	0	63, 270	10. 037	0	213, 052	1, 262, 617	1, 112, 988	726, 262	692, 079
Mar	0	244, 528	12, 398	0	0	995, 711	819, 110	827, 606	338. 808
Apr	0	236, 479	0	0	146, 360	846, 402	327, 178	534. 287	57, 825
May	49, 748	327, 311	0	0	397, 051	981, 043	575, 405	965, 211	81, 009
Jun	30, 920	327, 170	0	0	718, 244	1, 154. 531	743, 293	920, 254	48, 245
Jul	34, 789	335, 066	0	0	1, 692, 218	1, 242, 043	718, 427	736. 959	29. 407
Aug	23, 920	225, 028	0	0	1, 814, 390	1, 104, 628	700. 125	659, 154	53, 582
Sep	38, 318	351, 817	0	0	1, 712, 304	1, 074, 428	886, 208	696, 711	133, 580
Oct	71. 388	436. 164	0	0	1, 890, 907	1. 118, 320	707, 231	701, 778	183, 600
Nov	75, 927	468, 617	0	0	1, 349, 680	1, 153, 989	669, 700	602, 851	98, 558
Dec	0	386, 459	0	19. 345	1. 161, 689	1, 281. 992	799 405	731. 681	206. 562
Sums	329, 998	3, 495, 938	315, 265	19. 345	11. 681, 275	13, 576, 971	9, 323, 254	9. 098, 033	2. 941. 084

1/ Other excess releases to Mexico are taken from the Colorado River Board of California Water Report. They consist of measured delivery at NIB minus Mexico's schedule at NIB minus Minute water.

The other excess releases include 1) local rainfall which cannot be controlled and must be delivered to Mexico in excess of treaty requirements; 2) flows of the Gila River which cannot be used to meet treaty requirements (the maximum usable Gila flow in any year is approximately 1, 000, 000 acre-feet); and, 3) flood releases of mainstem Colorado River water.

Engineering judgement was used to determine when excess releases were caused by events such as rainfall rather than flood control.

Calculation Of Flood Control Releases From Hoover Dam

Other Excess Arrivals At Northerly International Boundary (Acre-feet)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Jan	354,014	37,077	3,760	13,013	378	130,016	160	7,486	113	189,893
Feb	125,940	3,291	25	237	143	451,669	78	1,083	281	255,296
Mar	8,719	2,296	276	647	13,796	1,180,811	674	86	239	172,865
Apr	11,206	368	431	247	13,407	795,122	119	19,150	421	32,406
May	3,603	350	334	209	12,141	452,937	3,318	23,216	93	125
Jun	1,828	340	259	108	386	199,879	63	76,538	441	920
Jul	224	11,305	278	59	83	84,253	129	78,316	51	1,153
Aug	65,674	15,956	21,940	451	17,924	52,863	1,964	5,580	176	216,860
Sep	21,883	10,465	12,500	2,717	753	67,662	775	245	35	
Oct	23,626	9,357	2,761	336	13,545	143,243	671	692	2,446	
Nov	10,157	439	158	276	1,466	125,744	3,199	834	126	
Dec	13,066	885	266	1,674	7,710	29,763	13,877	121	912	
Sums	630,831	89,932	41,988	20,873	80,732	3,692,761	25,017	212,324	5,333	789,118

Gila River Near Dome AZ

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Jan	729	98	135	248	275	181,300	15,470	2,120	1,930	1,110
Feb	770	76	87	146	331	595,700	9,240	1,240	1,310	1,010
Mar	1,120	708	134	221	16,750	1,388,000	9,000	933	1,110	1,170
Apr	627	345	88	221	98,000	939,600	8,470	50,090	742	810
May	440	1,000	86	200	55,980	565,600	8,710	135,000	451	895
Jun	93	597	68	162	13,560	296,100	5,500	156,700	301	217
Jul	87	4,110	306	179	534	165,400	2,410	155,200	144	305
Aug	155	2,830	1,880	77	198	123,000	651	15,410	498	
Sep	348	338	2,340	278	281	131,300	720	4,010	430	
Oct	492	330	300	161	406	157,300	1,010	2,600	702	
Nov	1,430	674	598	192	330	148,400	1,080	2,300	545	
Dec	144	223	235	251	329	35,320	2,140	2,400	935	
Sums	6,428	11,400	6,050	3,352	187,878	4,728,020	64,401	528,003	9,107	5,117

Calculated Flood Control Releases From Hoover Dam (Acre-feet) 1/

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Jan	354,165	36,979	0	0	0	0	0	0	0	108,583
Feb	125,171	0	0	0	0	0	0	0	0	254,286
Mar	7,599	0	0	0	0	0	0	0	0	171,695
Apr	10,579	0	0	0	0	0	0	0	0	31,706
May	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0
Aug	55,519	0	0	0	0	0	0	0	0	216,660
Sep	21,515	0	0	0	0	0	0	0	0	
Oct	23,134	0	0	0	0	0	0	0	0	
Nov	8,727	0	0	0	0	0	0	0	0	
Dec	12,924	0	0	0	0	0	0	0	0	
Sums	619,353	36,979	0	0	0	0	0	0	0	783,020

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STATE OF CALIFORNIA—THE RESOURCES AGENCY GRAY DAVIS, Governor

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Fax to Vickie Doyle IID (760) 339-9009 April 28, 1999

From Merlin Tostrud Colorado River Board of California
voice (818) 543-4676 extension 243

8 pages including cover

Vickie,

You asked me for information on IID uses 1940 and backward. The following pages are taken from a memo to Gerald Zimmerman from me, dated September 16, 1993, concerning historic California use of Colorado River water. You'll see, when reading the memo extracts, how the data were developed, and that I worked with IID in developing the information. If you have questions, or wish the data sent in a spreadsheet file via e-mail, let me know.

Merl

The following is taken from Sept 16, 1993 memo Tostrud to Zimmerman

drainage goes back to the river directly, not through drains, as unmeasured return flow. When the All-American Canal began diverting, seepage made the measured return flows from YPRD jump, almost doubling. A primary portion of the measured return flows was seepage from the AA Canal. To this date, returns from the YPRD have been strongly affected by the AA Canal seepage. My "95,000" studied this matter, as well as unmeasured returns from the YPRD, and concluded that crops were using 3.8 AF/Acre.

Hence, there are no good diversion records for YPRD until about 1953. And the measured return flows are even more problematic; much of YPRD drainage flows go unmeasured directly into the Colorado; and the drain water which is measured includes a significant amount of All-American Canal leakage. I've estimated that around half of the returns are All-American Canal leakage.

The only plausible method of determining YPRD use is to multiply 3.8 acre-feet per net acre times yearly acreage for YPRD. This data was available on an every-other-year basis for the period 1922 through 1954 in USBR crop report data. YPRD use was broken out between "whites" and "indians". "95,000" has yearly use based on this method of using acreage for both the Indian and Bard units of YPRD for the period 1960 on.

4. Imperial Irrigation District (IID): "The California Development Company was formed in 1896 to reclaim Imperial Valley with Colorado River water. A canal was excavated by the Company connecting the Colorado River with the Alamo River, which then was used as an unlined canal. In 1905, the Colorado River during flood stage broke through into the Imperial Valley and continued unchecked until February 1907. The Imperial Irrigation District was formed in 1911 under the California Irrigation District Act. In 1916, the District became the holder of rights to Colorado River water formerly held by the California Development Company." (From DWR Dec 1981 Investigation Under California Water Code Section 275 of Use Of Water")

The following, from "The Colorado River Flood Protection Works Of Imperial Irrigation District * History and Cost", by M. J. Dowd, helps explain the diversion of water into the Imperial Valley.

> "The work was started by a private company known as the California Development Company, diversion from the river being made on the California side a few hundred feet north of the Mexican boundary. From this point a canal -- then known as Imperial Canal and later called Alamo Canal -- was dug to the south parallel to the river a distance of some 4 or 5 miles to a connection with one of the old overflow channels of the Colorado known as the Alamo River. From that point the old alamo Channel was utilized for some 50

miles to Sharp's Heading and from there additional canals were constructed to take the water back into the United States.

"In order to operate in Mexico, the Company found it necessary to organize a subsidiary Mexican corporation (La Sociedad de Irrigacion y Terrenos de la Baja California, S. A.) and through the latter, a concession was obtained from the Mexican Government in May 1904 for such operations.

"As in other cases of expenditure of funds by the United States in Mexico, General Marshall found it necessary to carry on the work through a Mexican company. This time he utilized the Mexican subsidiary company of the California Development Company; however, dealings also had to be carried on with the revolutionary forces of General Villa."

Diversions to IID from the Colorado River were first made May 14, 1901 through the Alamo Canal. From February 14, 1942 on, all of IID's water came from the All-American Canal (USGS WSP 1313). Up to that point, IID and Mexico both used the Alamo Canal. The above quotes were given to point out problems in developing use by IID. We do have pretty good records of total diversions into the Alamo Canal in USGS Water Supply Paper 1313.

The reason this memorandum is being updated is that when it was originally written, the IID watermaster office was moving, and all records were packed in boxes. IID was contacted after its move to find out if a method existed for designating which portion of water diverted into the Alamo Canal went to IID, and which portion went to Mexico. In my earlier memo, I assumed 75% went to IID and 25% to Mexico. Mr. Jimmie L. Flowers, Watermaster of IID, sent us data entitled "*Imperial Irrigation District - Duty Of Water In Acre-Feet Per Acre - United States And Mexico*". The data sheets have "Acres Irrigated", "Acre-Feet Delivered", and "Acre-Feet Per Acre". It is not certain what "Acre-feet Delivered" means. Is this water delivered to farmers?, or to each country? If it is water delivered to farmers, does it have a 10% reduction in measured delivery as was IID's practice until 1963? This issue is not really important, because the numbers can be used only to allocate between IID and Mexico the total water delivered into the Alamo Canal.

Some water was diverted to IID from Volcano Lake from 1916 through 1921. The diversion averaged 151,100 acre-feet per year. The data heading in USGS WSP #1313 says "Diversions from Colorado River at Volcano Lake to Imperial Valley, Calif." I therefore added it to IID's use alone without prorating any of the Volcano Lake water to Mexico.

For the period of time IID was obtaining all of its water through the Alamo Canal, 1908-1939, there is a graph attached showing what percent deliveries to IID were of the total, and what percent IID's irrigated acreage was of the total. IID did not obtain any water from the Colorado River prior to 1901. I did not attempt showing IID deliveries for 1902-1907 because almost the entire flow of the Colorado, roughly fourteen million acre-feet per year, flowed by accident into the Alamo Canal in 1905 and 1906. Records of flow into the Alamo for 1901-1905 are sketchy, and IID did not begin its record keeping until 1908.

Totals during the period 1908-41, from IID data, show 70.02% of deliveries went to IID. The following table summarizes the data: (averages, in acre-feet/year):

Rockwood Heading Deliveries (IID+Mexico) ..	2,588,130
Average to IID	1,077,433
Average to Mexico	461,338
Total loss	1,049,359

The average loss, 1,049,359 acre-feet/year, was 40.55% of the deliveries into the Alamo Canal.

Problems 1940-1952

The period 1940-1952 presents some problems in determining IID use. Following is a table showing IID's delivery at Drop #1 on the All-American Canal; the IID use I decided to use; and the estimate I originally made in my September 1st memo.

	AA Can Drop #1 From IID	Number To Use	My Original Number
1940	76,372	2,033,000 a/	2,601,400 f/
1941	1,024,984	2,529,470 b/	2,557,670 g/
1942	2,407,922	2,457,900 e/	2,501,500 c/
1943	2,325,508	2,375,500 e/	2,455,440 c/
1944	2,445,002	2,495,000 e/	2,549,670 c/
1945	2,515,586	2,565,600 e/	2,753,610 c/
1946	2,697,450	2,747,500 e/	2,934,460 c/
1947	2,633,390	2,683,400 e/	2,950,740 c/
1948	2,699,314	2,777,000 d/	2,777,000 d/
1949	2,761,992	2,812,000 e/	2,741,500 h/
1950	2,938,666	2,988,700 e/	2,889,600 h/
1951	3,066,618	3,116,600 e/	2,993,900 h/
1952	3,203,411	3,253,400 e/	3,131,400 h/

a/ Delivery At Rockwood * Del to IID/Del to Mex from IID data
b/ All-American Canal at Pilot Knob-Pilot Knob Wasteway, (1,216,570 acre-feet) + Flow of Alamo Canal at Rockwood Heading allocated in the same manner as 1/ (1,312,900 acre-feet)
c/ USGS Wat Sup Paper 1313 PK-PKWasteway
d/ From IID Annual Report for IID @ Pilot Knob (PK)

e/ IID del at drop #1 + 50,000 for losses from 1117 to drop 1.
f/ Same as 1/ except Mex/IID split based on 75% to IID.
g/ Same as 2/ except Mex/IID split based on 75% to IID.
h/ IID del to users + 1,100,000 for losses and IID charging farmers only 90% of actual delivery.

Explanation of IID use 1940-1952. 1940: In 1940, IID obtained a very small amount of water at Drop #1 on the All-American Canal. There is no way to know if the water was ever delivered to IID, or was merely used by USBR for testing. Therefore, I used the method for the 1908-1939 period to determine IID's 1940 use, ignoring the Drop #1 water.

In 1941, IID obtained water from both the Alamo Canal and the All-American Canal. I estimated these values at 1,312,900 acre-feet from the Alamo, and 1,216,600 from the All-American Canal.

For the years 1942 through 1947, I originally subtracted flow through Pilot Knob Wasteway from flow of the All-American Canal above Pilot Knob Wasteway. The Colorado River Board of California water report accounts use by IID and CVWD at station 1117 on the All-American Canal, a station just below Pilot Knob. However, when the data came from IID for deliveries to IID at Drop #1, the Drop #1 flows were considerably lower than the results of subtracting PK Wasteway from AA Canal Above PK Wasteway. (Lower by roughly 10%.) An investigation of the data source, USGS Water Supply Paper #1313, found USGS saying that the flow of the AA Canal Above PK Wasteway was affected by backup of flow from Drop #1. The back water would have raised the elevation at the stage recorder without increasing the velocity, thus reporting a higher flow than when the gage was calibrated, prior to the construction of Drop #1. Hence, the AA Canal station above Pilot Knob was not an extremely accurate source of data.

For the period 1976-84, there was roughly 50,000 acre-feet of IID water lost to seepage between Station 1117 and Drop #1. Therefore, I added 50,000 acre-feet to IID's recorded flow at Drop #1 for the period 1942-1947.

1948: I found the value of 2,777,000 acre-feet discharged to IID below Pilot Knob in IID's annual report for the year. IID's records of 2,699,314 at Drop #1 show a loss to seepage for the year 1948 somewhat greater than 50,000 acre-feet. I chose to use the IID annual report value rather than adding 50,000 acre-feet to IID's flow at Drop #1 value.

For the years 1949 through 1952, I originally added 1,100,000 acre-feet to values for deliveries to farmers given in the IID annual reports. That was the only value given in the IID annual reports for those years. Water diverted below Pilot Knob wasn't listed. They only listed water delivered to farmers, and even those figures are low by 10%. (IID charged farmers 10% less than was actually delivered until 1963. It must be remembered that farmers were charged money on an acre-foot delivered basis.) The addition of 1,100,000 takes into account the average loss of water between station 1117 and the farmers' headgates of 900,000 acre-feet per year, and the 10% under-charge.

Since my original estimate of 1,100,000 acre-feet per year for addition to IID's delivery to farmers to arrive at flow at Station 1117 contained a much higher possible error than adding 50,000 acre-feet per year to IID's delivery at Drop #1 to arrive at flow at Station 1117, I used the latter.

5. Coachella Valley Water District (CVWD): Water was first taken from the Coachella Canal in March of 1948, though it was not taken with the District's sanction. Official delivery of water did not begin until 1949. Delivery to CVWD farmers in the first several years of operation were low, but the first forty-nine miles of the Coachella Canal leaked roughly 130,000 acre-feet of water prior to its lining in the early 1980s.

6. Fort Mojave Indian Reservation (FMIR): Development of FMIR did not begin until 1975. Records are those of USBR Article V, and include no return flow credits.

7. Miscellaneous California uses (MISC): Miscellaneous uses from 1964 on are those shown in USBR Article V records. Prior to that, I made a rough estimate of these uses based on use by YPRD. These miscellaneous uses from Article V are primarily pumpers on Yuma Island, and the Article V data shows no return flow credits. My estimates of miscellaneous uses prior to 1964 may be quite a bit in error, but these uses, relative to total California uses, are small.

PRIOR TO 1908

Up to the year 1901, the only uses of Colorado River water in California were by Palo Verde Irrigation District, farmers in the as-yet-unbuilt YPRD area, and some small miscellaneous uses along the river. The major user, PVID, did not farm more than 20,000 acres prior to 1901. In my opinion, it was impossible for California to have consumptively used more than 100,000 acre-feet per year prior to 1901. Imperial Irrigation District began diverting water for both itself and Mexico into the Alamo Canal in 1901. Records are inadequate to develop diversions prior to 1908. The accidental diversion of almost the entire flow of the Colorado River into the Alamo Canal from February 1905 until February 11, 1907 cannot be charged against California as consumptive use. It is impossible to estimate what IID diverted from 1901 through 1905. The physical features in place did not permit accurate control of the Alamo Canal intake, let alone

Calendar Year Consumptive Use Of Colorado River Water By California (Acre-feet)

	MWD	PVID DIV	PVID RET	PVID DIV-RET	YPRD DIV	YPRD RET	YPRD DIV-RET	IID	CVWD	FMIR	MISC	TOT
1908				78,000			5,000	674,800			5,000	762,800
1909				78,000			5,000	755,500			5,000	843,500
1910				78,000	17,500	9,900	7,600	857,200			8,000	950,800
1911				78,000	17,500	9,900	7,600	1,261,800			8,000	1,355,400
1912				78,000	26,300	14,900	11,400	1,320,400			11,000	1,420,800
1913				78,000	26,300	14,900	11,400	1,497,900			11,000	1,598,300
1914				78,000	26,300	14,900	11,400	1,623,700			11,000	1,724,100
1915				78,000	35,000	19,800	15,200	1,710,200			15,000	1,818,400
1916				78,000	35,000	19,800	15,200	1,872,600			15,000	1,980,800
1917				78,000	35,000	19,800	15,200	1,940,200			15,000	2,048,400
1918				78,000	39,400	22,300	17,100	2,138,400			17,000	2,250,500
1919				78,000	39,400	22,300	17,100	2,079,500			17,000	2,191,600
1920				78,000	39,400	22,300	17,100	2,194,900			17,000	2,307,000
1921				78,000	39,400	22,300	17,100	1,826,900			17,000	1,939,000
1922		131,100	74,200	56,900	4',400	23,500	17,900	1,832,100			18,000	1,924,900
1923		180,500	102,200	78,300	50,000	28,300	21,700	1,981,200			22,000	2,103,200
1924		200,000	113,200	86,800	58,500	33,100	25,400	1,943,300			25,000	2,080,500
1925		225,700	127,800	97,900	80,300	45,500	34,800	1,866,500			35,000	2,034,200
1926		212,000	120,000	92,000	102,100	57,800	44,300	1,929,700			44,000	2,110,000
1927		213,800	121,000	92,800	97,900	55,400	42,500	2,146,900			43,000	2,325,200
1928		169,600	96,000	73,600	93,800	53,100	40,700	2,215,700			41,000	2,371,000
1929		201,700	114,200	87,500	92,100	52,100	40,000	2,486,400			40,000	2,653,900
1930		179,600	101,700	77,900	90,300	51,100	39,200	2,545,700			39,000	2,701,800
1931		181,500	102,800	78,700	76,600	43,400	33,200	2,115,600			33,000	2,260,500
1932		162,500	92,000	70,500	62,900	35,600	27,300	2,149,700			27,000	2,274,500
1933		164,600	93,200	71,400	63,100	35,700	27,400	1,990,000			27,000	2,115,800
1934		194,400	110,100	84,300	63,300	35,900	27,400	1,336,400			27,000	1,475,100
1935		194,300	110,000	84,300	64,400	36,500	27,900	1,894,000			28,000	2,034,200

REVISED, *the early years*, P-9

	MWD	PVID DIV	PVID RET	PVID DIV-RET	YPRD DIV	YPRD RET	YPRD DIV-RET	IID	CVWD	FMIR	MISC	TOT
1936		225,500	127,600	97,900	65,600	37,100	28,500	2,151,400			29,000	2,308,800
1937		220,500	124,800	95,700	64,200	36,400	27,800	2,359,100			28,000	2,510,600
1938		226,700	128,300	98,400	62,900	35,600	27,300	2,310,700			27,000	2,463,400
1939	188,100	253,600	143,600	110,000	63,500	35,900	27,600	2,105,300			28,000	2,459,000
1940	91,300	360,200	203,900	156,300	64,000	36,300	27,700	2,033,000			28,000	2,336,300
1941	26,300	305,300	172,900	132,400	66,400	37,600	28,800	2,529,500			29,000	2,746,000
1942	26,800	340,100	192,600	147,500	68,800	38,900	29,900	2,457,900			30,000	2,692,100
1943	30,300	313,200	177,300	135,900	69,600	39,400	30,200	2,375,500			30,000	2,601,900
1944	47,300	335,800	190,100	145,700	70,400	39,900	30,500	2,495,000			31,000	2,749,500
1945	54,000	331,400	187,600	143,800	71,200	40,300	30,900	2,565,600			31,000	2,825,300
1946	76,000	408,700	231,400	177,300	72,000	40,800	31,200	2,747,500			31,000	3,063,000
1947	81,300	484,800	274,500	210,300	70,800	40,100	30,700	2,683,400			31,000	3,036,400
1948	189,900	558,900	316,400	242,500	69,500	39,400	30,100	2,777,000	164,800		30,000	3,434,300
1949	174,200	652,700	369,500	283,200	73,400	41,600	31,800	2,812,000	161,900		32,000	3,495,100
1950	175,000	767,700	434,600	333,100	77,400	43,800	33,600	2,988,700	342,600		34,000	3,907,000
1951	227,000	705,800	399,600	306,200	90,300	51,100	39,200	3,116,600	487,900		39,000	4,215,900
1952	170,700	728,800	412,600	316,200	103,200	58,400	44,800	3,253,400	495,600		45,000	4,325,700
1953	222,000	772,800	422,300	350,500	82,900	46,900	36,000	3,386,700	523,300		36,000	4,554,500
1954	334,200	864,600	451,700	412,900	88,600	50,200	38,400	3,151,800	572,200		38,000	4,547,500
1955	409,300	817,300	477,600	339,700	85,500	48,400	37,100	3,046,400	595,500		37,000	4,465,000
1956	473,100	949,400	555,400	394,000	88,300	50,000	38,300	2,998,300	565,200		38,000	4,506,900
1957	584,000	823,200	473,400	349,800	82,700	46,800	35,900	2,864,400	512,700		36,000	4,382,800
1958	530,600	871,100	506,800	364,300	77,400	43,800	33,600	2,785,900	501,800		34,000	4,250,200
1959	697,300	937,700	514,400	423,300	91,400	51,700	39,700	2,898,200	502,900		40,000	4,601,400
1960	877,700	927,500	544,600	382,900	95,200	53,900	41,300	3,059,800	505,800		41,000	4,908,500
1961	1,091,400	943,200	550,000	393,200	91,300	51,700	39,600	3,035,500	522,100		40,000	5,121,800
1962	1,063,100	952,800	580,400	372,400	97,500	55,200	42,300	3,006,100	564,700		42,000	5,090,600
1963	1,046,200	929,800	572,800	357,000	96,100	54,400	41,700	3,062,500	537,600		42,000	5,087,000
1964	1,129,400	927,900	530,100	397,800	96,500	53,400	43,100	2,807,700	511,100		43,000	4,932,100
1965	1,173,000	775,300	424,600	350,700	84,800	44,500	40,300	2,688,200	514,800		40,000	4,807,000

REVISED, the early years, P-10

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IMPERIAL IRRIGATION DISTRICT
RECORD OF RAINFALL IN INCHES

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1914	0.06	0.62	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.25	0.90	0.93	2.83
1915	2.30	0.02	0.10	0.28	0.00	0.00	0.00	0.60	0.02	0.00	0.00	0.00	3.32
1916	1.09	0.00	1.41	0.25	0.00	0.00	0.00	1.25	0.40	0.00	0.00	0.40	4.80
1917	1.32	0.00	0.00	0.10	0.00	0.00	0.20	0.00	0.02	Trace	0.00	0.00	1.64
1918	0.63	0.06	0.72	0.00	0.00	Trace	Trace	0.00	0.00	Trace	0.09	0.35	1.85
1919	0.08	0.40	0.26	0.00	0.02	0.00	0.08	0.00	0.89	0.28	0.84	Trace	2.85
1920	0.88	1.52	0.06	0.00	Trace	0.00	Trace	1.05	1.30	0.10	0.00	0.00	4.91
1921	0.47	0.00	0.03	0.00	0.12	0.00	0.06	2.84	0.85	0.00	0.00	1.66	6.03
1922	0.68	0.75	Trace	0.00	Trace	Trace	0.78	Trace	0.11	0.00	0.22	0.03	2.57
1923	0.09	0.10	0.40	0.20	0.00	0.00	0.02	0.02	0.59	0.02	1.29	0.78	3.51
1924	0.00	0.00	0.17	Trace	0.14	Trace	Trace	0.00	0.02	0.00	0.00	0.33	0.66
1925	Trace	0.03	0.24	0.09	0.00	0.00	Trace	0.16	Trace	1.62	0.30	0.50	2.94
1926	0.17	0.00	0.02	1.11	0.00	0.00	0.00	0.05	1.30	0.00	0.00	3.87	6.52
1927	0.12	0.64	0.11	0.02	0.00	0.00	Trace	Trace	0.00	0.89	0.00	2.92	4.70
1928	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	Trace	Trace	0.28
1929	0.15	Trace	0.00	Trace	Trace	Trace	Trace	0.26	1.23	0.00	Trace	Trace	1.64
1930	0.35	Trace	0.38	0.03	0.41	Trace	Trace	Trace	0.73	0.00	Trace	0.00	1.90
1931	0.06	1.90	0.00	0.93	0.00	0.00	0.05	0.51	0.57	0.10	0.33	0.30	4.75
1932	0.00	1.14	0.00	0.00	0.00	Trace	0.00	0.00	0.00	2.86	0.00	0.62	4.62
1933	0.47	Trace	0.00	0.79	0.02	0.00	0.10	0.63	0.01	0.30	0.06	Trace	2.38
1934	0.01	0.18	0.08	0.00	0.00	0.00	0.01	0.08	0.00	Trace	0.01	0.25	0.62
1935	0.62	2.12	0.12	Trace	Trace	0.00	0.12	1.14	0.50	0.00	Trace	0.70	5.32
1936	0.25	0.57	0.00	0.00	0.00	0.00	0.25	Trace	0.00	0.10	0.21	0.21	1.59
1937	0.19	0.10	0.61	0.00	Trace	0.00	0.35	0.00	0.15	0.00	0.00	0.09	1.49
1938	Trace	1.19	0.59	0.00	0.00	0.00	0.47	0.23	0.00	0.00	0.00	1.36	3.84
1939	0.73	0.45	Trace	0.00	0.00	0.00	0.00	0.00	7.06	Trace	0.28	Trace	8.52
1940	0.05	0.77	0.01	0.01	0.00	0.00	0.00	0.00	1.73	0.07	0.05	2.38	5.07
1941	0.85	0.30	1.10	0.46	0.01	0.00	0.06	1.08	0.28	1.04	0.10	1.34	6.62
1942	0.13	0.74	0.55	0.41	0.00	0.00	0.00	0.65	0.00	0.01	0.00	0.00	2.49
1943	0.44	0.04	0.24	Trace	0.00	0.00	0.00	0.90	0.38	0.00	0.00	2.46	4.46
1944	0.01	1.31	0.13	0.05	0.00	0.00	0.00	0.00	0.00	0.04	0.90	1.15	3.59
1945	0.57	0.07	0.03	0.03	0.00	0.00	Trace	1.44	Trace	Trace	0.00	0.67	2.81
1946	0.01	0.00	Trace	Trace	0.00	0.00	0.01	2.16	0.05	0.21	0.14	0.57	3.15
1947	0.00	0.00	0.02	0.06	0.00	0.00	0.00	0.06	0.08	0.03	0.10	0.14	0.49
1948	0.00	0.15	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.81	0.00	0.29	1.33
1949	1.77	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.04	0.20	0.03	0.19	2.29
1950	0.00	0.19	0.00	0.00	Trace	0.00	0.17	0.00	0.06	0.00	0.00	0.03	0.45
1951	0.38	0.01	0.01	0.13	0.00	0.00	0.18	1.79	0.00	Trace	0.26	0.36	3.12
1952	0.63	0.05	0.40	0.42	0.00	0.00	0.03	0.28	0.00	0.00	0.64	0.19	2.64
1953	0.00	0.02	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
1954	0.53	0.00	0.18	0.00	0.00	0.00	0.06	0.00	0.03	0.00	0.00	0.03	0.83
1955	1.60	0.00	0.06	0.00	0.00	0.00	0.29	0.53	0.00	0.00	0.00	0.05	2.53
1956	0.13	0.01	0.00	Trace	0.01	0.00	Trace	0.00	Trace	0.00	0.00	0.01	0.16
1957	0.63	0.04	0.07	0.03	0.00	0.00	0.00	0.45	0.00	2.04	0.02	0.07	3.35
1958	0.08	1.24	0.64	0.61	0.13	0.00	0.00	0.00	0.00	0.00	0.01	0.00	2.71
1959	0.15	0.23	Trace	Trace	0.00	0.00	0.02	0.02	0.11	0.40	0.01	1.03	1.97
1960	0.50	0.15	0.30	0.00	0.01	0.00	0.03	0.01	0.53	Trace	0.14	0.07	1.74

IMPERIAL IRRIGATION DISTRICT
RECORD OF RAINFALL IN INCHES

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1961	0.20	0.00	0.00	0.00	0.00	0.00	0.04	0.75	0.00	0.00	0.05	0.83	1.87
1962	0.77	0.23	0.05	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.78	1.85
1963	0.06	0.14	0.18	0.00	0.00	0.00	0.00	0.30	1.06	0.23	0.46	0.00	2.43
1964	0.01	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.29	0.01	0.93
1965	0.04	0.22	0.10	0.72	0.00	0.00	Trace	0.00	0.00	0.00	0.24	1.89	3.21
1966	0.32	0.10	0.18	0.00	0.00	0.00	0.00	0.00	0.47	0.48	0.06	0.00	1.61
1967	0.34	0.00	0.12	Trace	0.00	0.00	0.00	0.21	1.31	0.00	1.50	0.77	4.25
1968	0.00	0.06	0.58	0.00	0.00	0.00	1.31	0.00	0.00	0.00	0.00	0.04	1.99
1969	0.92	0.08	0.02	0.00	0.00	0.00	0.00	0.01	0.82	0.02	1.51	0.12	3.50
1970	0.00	0.69	0.83	0.00	0.00	0.00	0.00	0.02	0.03	Trace	0.02	0.09	1.68
1971	0.10	0.01	0.00	0.13	0.00	0.00	0.00	0.32	0.44	0.18	0.00	0.11	1.29
1972	0.00	0.00	0.00	0.00	0.00	Trace	0.00	0.00	Trace	1.71	0.45	0.00	2.16
1973	0.03	0.58	0.31	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.09	0.00	1.28
1974	1.11	0.00	0.18	0.00	0.00	0.00	0.04	0.00	0.09	0.12	0.00	0.44	1.98
1975	0.07	0.00	0.16	0.47	0.00	0.00	0.20	0.00	0.17	0.00	0.00	0.12	1.19
1976	0.00	0.84	0.00	0.36	0.02	0.00	0.29	0.00	2.84	0.00	0.58	0.15	5.08
1977	0.05	0.02	0.04	0.00	0.00	0.00	0.01	3.87	0.00	0.29	0.00	0.93	5.21
1978	1.15	0.46	0.39	0.09	0.00	0.00	0.47	0.00	0.00	0.65	0.57	0.59	4.37
1979	1.09	0.09	0.60	0.00	0.09	0.00	0.07	0.40	0.01	0.00	0.00	0.00	2.35
1980	1.59	1.41	1.06	0.23	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	4.35
1981	0.88	0.36	0.60	0.00	0.05	0.00	0.00	0.36	Trace	0.00	0.27	0.00	2.52
1982	0.31	0.09	0.82	0.00	0.00	0.00	0.00	0.49	0.63	0.00	0.10	2.40	4.84
1983	0.23	1.25	1.64	Trace	0.00	0.00	0.00	1.21	0.79	0.00	0.00	0.60	5.72
1984	0.20	0.00	0.00	0.00	0.00	0.00	0.76	0.81	0.03	0.00	0.20	1.43	3.43
1985	0.03	0.12	0.00	0.00	0.00	0.00	0.02	0.15	1.40	0.36	0.90	0.76	3.74
1986	0.14	0.50	0.12	0.00	0.00	0.00	0.06	0.05	0.04	2.59	0.19	0.04	3.73
1987	0.05	0.22	Trace	0.00	Trace	0.00	0.00	0.14	0.01	1.12	0.72	0.32	2.58
1988	0.11	0.90	0.00	0.07	0.00	0.01	0.04	0.12	0.00	0.00	0.07	0.00	1.32
1989	0.65	0.00	0.01	0.00	0.00	0.00	0.00	0.09	0.00	Trace	0.00	0.00	0.75
1990	0.14	0.02	0.06	0.05	0.00	0.00	0.00	0.89	0.09	0.21	0.00	0.00	1.46
1991	0.54	0.62	0.72	0.00	0.00	0.00	0.47	Trace	0.59	0.02	0.35	1.26	4.57
1992	0.37	0.95	1.85	0.08	0.17	0.00	0.00	0.02	0.00	0.45	0.00	1.36	5.25
1993	3.45	0.84	0.15	0.00	0.03	0.00	0.00	0.03	0.00	0.03	0.80	0.01	5.34
1994	0.06	0.49	0.64	0.00	0.72	0.00	0.00	0.08	0.02	0.00	0.26	0.78	3.05
1995	1.50	0.21	0.07	0.29	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.05	2.16
1996	0.00	0.15	0.04	0.00	0.00	0.00	0.57	0.01	0.00	0.00	0.03	0.02	0.82
1997	0.49	0.01	0.00	0.02	0.08	0.01	0.00	0.00	2.11	0.00	0.01	0.91	3.64
1998	0.15	1.08	0.73	0.00	0.00	0.00	0.00	0.06	1.08	0.00	0.04	0.12	3.26
1999	0.00	0.29	0.00	0.47	0.00	0.00	0.73	0.18	0.34	0.00	0.00	0.00	2.01
2000	0.00	0.19	0.09	0.00	0.00	0.00	0.00	0.08	0.04	0.52	0.03	0.00	0.95
2001	0.30	0.75	0.61	0.00	Trace	0.00	0.00	0.00	0.00	0.00	0.01	Trace	1.67
2002	Trace	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	Trace	0.18	0.06	0.66
2002 Total to Date	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.42	0.60	0.66	0.66
89 Year Average	0.41	0.36	0.25	0.10	0.02	0.00	0.10	0.33	0.38	0.23	0.19	0.49	2.86
Total to Date	0.41	0.77	1.02	1.12	1.14	1.14	1.24	1.57	1.95	2.18	2.37	2.86	2.86

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IMPERIAL IRRIGATION DISTRICT

MAXIMUM, MINIMUM AND MEAN TEMPERATURES BY MONTHS FOR YEARS 1914-2002, INCLUSIVE

	JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE			JULY		
Year	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1914	No records for these months												100	51	75.4	112	58	84.4	110	70	89.8
1915	73	30	53.5	79	40	59.2	92	41	63.4	96	48	69.0	103	41	73.3	109	57	85.1	110	62	88.9
1916	75	25	52.3	88	29	61.8	100	42	67.8	100	44	71.8	105	50	75.9	116	55	85.4	111	62	89.9
1917	76	30	50.4	82	32	57.4	93	32	58.8	98	41	66.7	99	48	71.0	117	56	85.5	113	70	91.3
1918	85	26	53.7	88	28	57.1	95	40	64.7	96	44	69.5	98	50	73.0	113	59	88.7	110	59	89.6
1919	82	24	51.6	82	32	56.1	89	35	60.4	100	48	71.8	101	55	77.0	114	57	85.4	111	73	90.7
1920	81	33	55.6	82	41	60.5	85	38	61.1	96	44	68.0	106	41	76.2	108	58	82.8	115	63	91.3
1921	79	28	52.2	93	32	54.2	93	41	66.3	102	40	66.9	104	46	72.5	110	57	84.2	111	63	91.0
1922	75	23	49.5	90	28	55.7	89	32	58.8	96	40	65.1	106	46	77.1	114	62	86.5	111	69	90.3
1923	85	28	56.1	87	30	56.7	89	34	60.4	95	42	67.8	107	52	78.1	114	54	79.5	113	67	88.6
1924	81	27	53.6	91	37	64.2	92	38	66.0	95	39	70.4	107	53	79.8	113	60	88.9	111	65	89.8
1925	82	27	52.6	85	35	61.2	94	39	64.4	100	44	70.7	103	54	78.6	114	55	84.3	115	64	90.6
1926	85	29	53.9	88	33	61.5	91	42	66.9	105	50	73.0	104	55	78.6	113	62	86.9	112	62	90.3
1927	76	32	55.3	87	34	59.6	92	38	62.2	102	41	70.8	110	53	78.7	111	54	84.0	114	68	91.7
1928	86	29	56.2	84	33	57.6	91	42	66.0	96	39	69.6	105	53	77.9	112	57	85.2	114	62	90.3
1929	79	25	50.7	88	24	55.0	95	36	61.9	98	36	66.0	102	49	77.7	117	54	83.9	111	69	90.7
1930	77	28	52.7	89	34	61.0	92	34	62.4	99	45	71.9	104	43	71.7	112	57	83.4	112	68	90.2
1931	85	29	54.8	76	38	58.5	95	37	64.5	97	51	72.5	108	55	80.0	111	58	84.7	116	75	95.2
1932	75	25	49.7	87	28	57.2	94	40	64.1	98	47	69.2	102	52	76.9	110	58	84.2	111	63	89.9
1933	76	29	50.2	78	23	51.1	87	39	63.4	96	45	66.2	106	44	73.4	111	57	84.0	117	65	92.9
1934	81	30	56.5	82	40	62.9	101	42	72.6	102	42	75.5	112	54	82.2	106	52	80.5	118	66	93.7
1935	84	29	55.4	84	36	60.1	89	36	60.1	95	43	69.7	102	51	75.0	113	58	88.6	113	61	90.2
1936	78	31	54.9	83	35	59.3	93	41	67.2	101	43	73.3	106	51	80.6	117	54	88.0	119	63	92.4
1937	68	16	43.8	82	31	55.7	88	41	61.2	98	46	69.0	108	53	77.2	110	58	84.7	117	72	94.6
1938	80	33	56.8	82	34	57.1	88	38	61.4	105	40	69.7	111	50	77.9	112	58	85.7	115	62	91.7
1939	78	35	53.6	81	32	42.3	95	32	63.4	102	48	73.2	108	55	79.2	114	59	85.1	118	66	92.2
1940	83	32	57.8	83	35	58.5	91	39	66.8	103	52	72.3	108	61	82.7	117	62	88.4	116	61	90.8
1941	74	38	56.5	78	44	61.0	87	43	63.8	95	45	67.3	105	48	79.6	108	58	83.4	114	66	91.6
1942	80	27	56.4	78	33	56.3	93	38	62.5	94	45	69.1	110	46	76.7	113	58	85.6	118	71	94.5
1943	85	25	55.6	85	32	60.5	95	44	67.0	100	45	72.1	106	55	79.0	110	53	81.5	119	62	89.9
1944	80	31	53.9	78	32	54.5	88	39	61.3	99	47	69.3	100	50	76.3	110	57	79.9	112	64	87.9
1945	81	33	55.9	82	36	58.5	88	37	60.3	100	35	68.5	100	54	76.1	114	58	83.5	113	72	91.9
1946	78	31	54.9	86	31	56.3	87	40	62.3	101	44	73.1	103	56	77.0	111	60	87.6	111	67	91.5
1947	83	28	52.9	85	39	61.7	88	42	64.8	104	45	72.9	116	52	79.7	110	61	84.7	113	67	92.3
1948	84	25	54.8	85	26	56.9	85	35	59.0	100	41	70.5	104	50	77.3	114	54	83.7	113	65	89.8
1949	71	21	45.3	82	28	53.8	85	41	61.6	102	45	73.3	106	53	77.0	110	57	86.1	115	66	90.7
1950	82	21	51.7	85	34	61.0	95	36	64.9	101	45	73.6	103	49	75.5	118	57	83.6	117	65	89.8
1951	84	32	54.4	88	31	57.5	88	33	62.4	98	46	69.7	111	47	77.4	110	56	83.2	113	63	91.4
1952	75	26	51.4	81	35	58.0	87	37	59.4	95	50	69.5	105	56	81.6	110	55	82.7	111	67	90.5
1953	86	34	59.9	85	30	58.3	91	35	63.5	97	44	68.4	99	49	72.4	113	53	83.6	114	72	93.6
1954	84	31	56.0	92	41	64.4	90	37	61.9	103	45	74.5	102	50	78.0	112	53	83.5	116	71	92.9
1955	77	35	51.9	83	29	55.2	92	35	63.6	88	50	69.0	103	48	74.9	113	55	84.1	113	64	88.7
1956	80	35	58.1	80	29	54.3	93	33	64.9	98	41	68.9	104	52	76.8	113	59	87.1	110	64	90.2
1957	74	30	54.6	89	34	63.7	91	40	64.9	94	45	69.8	102	55	73.8	117	62	88.7	116	71	93.1
1958	80	35	57.5	81	40	61.6	80	38	60.7	102	42	70.4	109	54	82.6	112	61	86.1	117	67	91.2
1959	85	33	58.3	83	37	57.3	91	41	66.9	102	49	74.3	99	51	76.1	116	62	88.8	113	73	94.3
1960	79	27	52.1	81	31	56.9	92	43	67.8	97	47	73.1	109	52	77.8	113	65	89.6	115	69	93.1
1961	83	34	58.0	82	38	60.9	89	43	64.3	103	50	72.3	102	50	76.0	116	56	88.1	114	64	91.2

IMPERIAL IRRIGATION DISTRICT

MAXIMUM, MINIMUM AND MEAN TEMPERATURES BY MONTHS FOR YEARS 1914-2002, INCLUSIVE

	JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE			JULY		
Year	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1962	87	25	55.4	81	28	59.1	89	32	59.7	101	50	74.5	101	48	73.5	111	57	84.4	110	68	90.4
1963	73	24	52.0	90	42	65.3	88	39	62.6	95	43	67.5	104	52	79.2	110	51	82.0	114	69	91.1
1964	77	30	52.0	80	32	56.2	91	36	61.5	99	47	68.4	102	45	76.2	112	60	84.0	116	72	92.1
1965	82	33	57.2	88	31	59.5	84	36	62.1	101	44	70.1	105	52	76.9	105	57	80.6	113	69	90.6
1966	77	30	52.8	77	32	55.9	97	34	65.7	98	49	73.6	103	58	80.4	110	62	86.3	115	71	92.3
1967	81	30	55.4	85	38	60.3	91	42	66.0	88	45	63.3	107	48	76.5	111	57	82.7	113	75	93.3
1968	79	33	55.7	90	44	65.4	92	44	66.0	98	46	69.5	108	55	78.7	115	60	86.6	114	68	91.4
1969	82	33	59.5	76	36	57.5	96	38	63.3	95	49	71.1	107	54	80.1	109	62	82.9	115	67	92.8
1970	79	29	55.3	83	39	61.6	90	43	63.9	94	43	66.9	109	53	78.8	119	58	86.8	113	71	93.1
1971	90	23	55.3	89	31	59.2	98	32	64.8	94	44	68.5	99	54	73.8	112	54	84.2	113	67	92.3
1972	75	24	52.9	86	30	61.8	94	46	70.8	96	42	71.7	102	54	78.3	114	66	86.0	116	73	94.0
1973	77	30	53.3	77	40	59.5	80	43	60.7	97	46	68.5	107	54	80.1	117	57	87.9	115	70	91.2
1974	81	28	56.0	81	38	58.3	90	40	65.6	96	47	70.5	111	51	78.7	116	59	89.4	112	69	91.2
1975	83	31	55.1	83	34	57.6	86	40	61.5	88	42	63.7	105	50	75.8	110	59	85.1	115	71	91.7
1976	86	29	57.2	84	40	60.9	89	42	63.0	99	45	67.7	106	55	79.3	115	50	86.8	115	66	90.6
1977	80	33	56.7	91	39	63.3	87	39	60.8	98	43	72.2	105	53	72.6	115	66	88.3	113	72	93.0
1978	76	37	57.4	82	39	60.6	95	47	67.6	93	48	69.3	107	54	78.7	115	62	90.9	116	68	93.6
1979	74	31	52.6	79	35	58.9	89	42	64.1	97	46	71.9	102	52	77.2	115	61	87.6	115	68	91.9
1980	77	38	60.1	85	39	63.2	86	46	63.3	101	46	70.7	101	52	73.9	114	59	87.4	116	73	94.9
1981	83	42	60.9	90	39	61.8	91	44	64.4	97	47	72.9	103	56	78.4	114	65	90.5	112	73	93.2
1982	76	33	55.8	86	37	61.7	83	41	63.5	94	44	76.7	101	52	70.9	108	59	82.8	113	61	90.5
1983	82	35	59.0	85	42	60.5	90	46	65.2	90	45	66.7	114	52	78.9	108	57	84.3	114	67	92.0
1984	82	35	58.7	83	38	60.3	95	40	66.7	101	48	70.2	111	58	83.0	111	61	85.7	112	75	91.9
1985	73	36	54.8	85	28	57.6	86	39	63.8	101	54	74.3	101	57	79.2	114	61	88.6	116	72	93.3
1986	85	38	61.4	96	34	63.4	99	44	69.5	102	51	72.6	106	53	79.7	114	64	89.2	115	70	91.2
1987	83	31	55.1	82	39	60.0	85	41	64.0	101	50	75.9	104	56	78.8	114	65	88.1	112	64	89.8
1988	79	32	55.5	84	37	61.9	99	40	66.4	101	45	70.7	108	50	77.4	108	54	85.1	111	69	91.6
1989	78	32	54.1	93	30	59.9	96	42	68.8	105	51	76.8	106	54	79.4	111	62	86.9	114	69	92.7
1990	78	31	54.9	86	29	57.9	93	41	66.4	99	53	73.6	102	54	76.9	117	59	87.3	114	69	92.2
1991	77	31	54.9	85	39	64.3	82	38	60.2	98	45	70.1	102	51	75.0	106	60	82.0	112	69	88.8
1992	80	35	55.8	83	44	62.4	85	45	63.9	101	51	74.3	99	60	79.8	108	62	84.6	114	65	89.5
1993	74	29	54.0	78	40	58.6	90	44	67.5	101	50	73.3	100	52	79.1	114	57	86.9	113	67	89.4
1994	82	34	57.5	80	33	56.9	92	44	67.1	100	48	71.3	105	51	75.9	115	63	88.7	112	67	92.3
1995	78	37	55.4	87	42	64.3	90	40	64.7	97	41	68.8	102	52	73.1	111	54	82.8	121	68	91.5
1996	82	34	57.8	87	35	62.7	91	43	66.2	103	52	72.7	108	57	80.7	110	53	86.1	115	61	91.1
1997	78	37	57.0	83	34	58.0	94	37	66.6	97	41	69.7	107	59	82.5	107	57	83.4	113	63	88.4
1998	79	34	56.5	75	40	57.4	91	41	62.6	98	44	67.0	95	51	72.9	114	55	81.9	116	68	91.7
1999	77	36	56.7	84	36	59.0	90	42	61.8	100	41	65.0	105	48	76.3	110	52	83.6	111	69	89.7
2000	82	35	59.1	80	41	61.6	89	43	64.6	101	50	74.8	112	55	81.9	111	61	88.4	113	66	91.6
2001	79	37	55.0	84	36	57.7	94	44	66.9	99	46	70.0	112	55	83.9	112	66	89.4	115	69	91.6
2002	82	33	56.0	86	32	60.3	93	35	63.6	99	50	72.2	106	56	78.3	112	66	88.4	113	72	93.0
Average	79.7	30.6	54.9	84.1	34.7	59.1	90.7	39.5	64.0	98.4	45.5	70.5	104.9	52.0	77.5	112.3	58.2	85.5	113.8	67.4	91.4

IMPERIAL IRRIGATION DISTRICT

MAXIMUM, MINIMUM AND MEAN TEMPERATURES BY MONTHS FOR YEARS 1914-2002, INCLUSIVE

	AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER			FOR YEAR				MEAN FOR
Year	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Date	Min.	Date	YEAR
1914	113	64	88.7	108	60	84.1	100	52	73.4	91	41	65.6	No Record			113	8-3	Incomplete		
1915	117	64	90.6	109	52	81.2	104	50	75.5	91	30	60.8	82	28	54.1	117	8-10	28	12-17	71.2
1916	111	56	87.7	110	57	83.1	95	43	68.2	90	30	58.5	79	25	51.2	116	6-15	25	1-12	71.1
1917	109	62	88.9	108	53	85.3	106	44	76.2	90	38	63.7	89	31	58.3	117	6-16	30	1-5	71.0
1918	114	55	86.7	105	56	83.1	110	44	74.7	86	32	59.4	82	28	50.5	114	8-2	26	1-11	70.9
1919	113	67	90.3	107	60	83.7	94	36	68.3	88	31	59.7	82	31	55.6	114	6-26	24	1-1	70.9
1920	111	58	87.8	108	53	81.8	102	41	65.7	86	34	58.2	78	29	52.9	115	7-8	29	12-14	70.1
1921	110	68	88.5	107	57	82.6	103	43	75.1	93	32	62.2	81	33	53.4	111	7-22	28	1-12	70.8
1922	110	67	88.8	113	59	87.2	100	42	73.3	85	34	58.2	79	34	56.6	114	6-29	23	1-23	70.6
1923	107	67	87.6	109	51	80.7	97	44	69.7	83	35	62.1	78	32	52.8	114	6-28	28	1-3	70.2
1924	113	61	89.0	108	48	84.2	100	44	69.4	93	34	61.6	83	23	53.1	113	6-28	23	12-26	72.5
1925	109	67	88.0	104	52	80.7	101	46	70.4	90	33	60.4	80	31	56.0	115	7-16	27	1-11	71.1
1926	110	63	89.4	106	53	82.6	100	44	73.1	92	39	63.4	78	27	52.1	113	6-26	27	12-27	72.6
1927	115	72	90.9	106	56	82.8	101	43	73.8	98	37	63.9	85	31	53.4	115	8-10	31	12-8	72.3
1928	113	60	88.5	113	54	85.5	102	45	72.2	88	31	61.2	79	29	53.0	114	7-24	29	1-18 & 12-17/21	71.9
1929	111	73	90.5	112	54	80.8	104	40	73.8	88	30	59.2	84	31	58.0	117	6-24	24	2-8/9	70.8
1930	110	63	87.6	110	51	79.7	100	46	70.2	92	31	61.0	77	26	51.5	112	6-7 & 7-2, 11, 15	26	12-22	70.3
1931	112	70	89.9	111	58	83.0	98	51	73.1	93	27	58.0	75	28	51.1	116	7-2	27	11-23/25	72.2
1932	114	62	89.9	112	60	85.6	102	45	71.8	87	40	63.2	80	30	50.8	114	8-5	25	1-27	71.0
1933	118	67	91.5	109	59	84.9	105	50	77.9	91	37	63.5	82	29	55.8	118	8-11	23	2-8	71.2
1934	117	71	94.0	114	53	86.5	109	49	77.5	94	38	65.6	81	31	57.2	118	7-26/27, 7-30/31	30	1-9	75.5
1935	115	70	90.6	109	63	87.4	99	42	72.9	81	36	59.5	78	33	56.1	115	8-11	29	1-22	72.2
1936	112	67	91.8	108	52	83.7	103	47	74.2	90	36	62.3	76	32	54.8	119	7-14/16	31	1-19	73.6
1937	115	65	93.6	112	61	88.3	99	54	75.9	91	40	64.3	82	33	58.7	117	7-2	16	1-22	72.4
1938	114	65	90.7	108	64	87.2	101	46	72.5	84	29	57.2	88	35	57.3	115	7-19	29	11-25/28	72.2
1939	111	75	92.7	112	58	82.1	95	44	72.4	91	44	64.7	85	32	59.7	118	7-13	32	2-3/10 3-1; 12-28	72.7
1940	117	66	92.3	110	62	84.3	101	48	75.1	86	38	61.1	85	30	58.6	117	6-13	30	12-15	74.1
1941	109	65	87.2	104	53	79.1	100	47	69.5	91	30	64.2	82	37	56.6	114	7-10/20	30	11-20	71.7
1942	113	62	91.8	109	60	84.1	101	45	73.9	88	36	63.3	81	32	57.1	118	7-24/25	27	1-7	72.6
1943	110	67	88.9	113	64	87.7	105	45	74.8	86	36	62.3	74	35	54.7	119	7-25	25	1-19	73.0
1944	115	65	91.5	111	57	85.7	101	55	76.1	85	35	60.9	77	33	55.9	115	8-11	31	1-9/10	71.2
1945	110	68	90.2	114	56	86.7	101	49	76.2	91	39	61.7	80	31	54.1	114	6-19 & 9-5	31	12-14/16	72.1
1946	113	68	92.0	111	63	86.6	96	46	70.1	81	38	59.0	82	35	57.3	113	8-2	31	1-11/31; 2-3	72.4
1947	113	60	89.2	113	64	87.5	105	49	74.5	89	30	57.9	74	28	51.6	116	5-3	28	1-4 & 12/14	72.4
1948	115	65	91.3	118	54	87.0	103	46	75.5	83	34	58.9	76	31	52.1	118	9-3	25	1-1	71.4
1949	114	61	89.8	112	64	89.7	102	41	71.5	93	43	67.8	87	26	52.8	115	7-14	21	1-4	71.6
1950	116	66	90.5	118	58	82.8	106	54	78.7	98	34	67.2	84	35	60.6	118	6-30 & 9-1	21	1-4	73.3
1951	111	66	89.6	109	62	86.8	105	50	75.6	85	38	60.7	78	30	54.6	113	7-31	30	12-9	71.9
1952	112	72	92.2	112	51	87.6	108	57	81.6	88	34	58.9	84	32	55.1	112	8-3 & 9-1/2	26	1-4	72.4
1953	111	61	90.6	111	61	86.4	101	48	75.2	90	37	64.6	82	26	54.6	114	7-2	26	12-25	72.7
1954	113	66	88.9	108	54	86.5	101	46	76.5	89	43	66.9	79	27	55.7	116	7-28	27	12-29	73.8
1955	110	72	90.9	113	60	86.5	104	52	77.7	89	40	63.4	84	37	57.8	113	6-9/22	29	2-20	72.0

IMPERIAL IRRIGATION DISTRICT

MAXIMUM, MINIMUM AND MEAN TEMPERATURES BY MONTHS FOR YEARS 1914-2002, INCLUSIVE

	AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER			FOR YEAR				MEAN FOR
Year	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Date	Min.	Date	YEAR
1956	111	60	88.3	113	64	90.5	100	44	73.5	92	33	62.0	81	29	56.7	113	6-12, 9- 2	29	2- 3, 12- 9	72.7
1957	114	63	90.3	110	61	86.3	101	51	71.9	82	37	60.3	82	36	57.9	117	6-24	30	1-27	73.0
1958	111	77	92.9	109	60	87.7	103	50	78.3	90	32	63.3	90	36	59.6	117	7- 9	32	11-17	74.4
1959	112	66	90.6	111	60	83.7	101	45	76.5	88	36	64.6	83	36	56.1	116	6-22	33	1- 5	73.9
1960	115	69	91.5	111	64	88.5	103	50	75.2	90	39	62.7	78	28	54.9	115	7-16 & 8-13	27	1- 3	73.6
1961	111	64	90.7	105	59	82.6	103	43	73.5	83	37	60.5	77	33	55.2	116	6-25	33	12-12	72.8
1962	113	69	93.6	110	61	87.1	102	55	76.0	93	42	66.3	83	34	58.0	113	8-25	25	1-12	73.2
1963	110	72	90.3	111	66	87.3	102	58	78.1	89	42	64.5	80	33	56.0	114	7-14	24	1-13, 14	73.0
1964	111	68	90.5	107	61	83.7	105	55	79.3	86	33	60.7	85	32	56.8	116	7-12	30	1- 9, 10	71.9
1965	111	70	91.2	110	58	82.0	105	53	78.4	90	41	66.0	80	36	55.2	113	7- 4	31	2-12	72.6
1966	111	70	92.6	109	62	86.1	95	49	74.6	94	43	65.1	82	32	57.4	115	7- 6	30	1- 4, 22	73.7
1967	113	74	93.5	104	65	85.5	97	54	77.7	94	44	67.9	78	33	53.2	113	7- 1,2, & 8-29	30	1- 7	73.0
1968	108	65	88.6	113	58	85.5	98	53	76.0	88	42	65.9	75	27	52.4	115	6-22	27	12-22	73.5
1969	117	75	95.9	113	65	88.7	102	51	72.5	89	42	64.7	77	33	57.7	117	8- 4	33	1-30	74.0
1970	114	72	93.5	111	57	84.5	98	42	72.9	87	43	63.8	78	37	55.2	119	6-25	29	1- 3	73.1
1971	110	71	91.3	115	56	85.6	102	36	69.9	87	39	61.7	72	31	52.5	115	9-12	23	1- 5, 7	71.7
1972	116	68	89.5	107	61	84.2	104	52	72.0	84	41	60.5	78	28	54.2	116	7-31 & 8- 1	24	1- 5	73.0
1973	111	64	91.0	110	60	83.8	99	50	75.4	92	40	63.9	80	37	57.5	117	6-27	30	1- 6, 7	72.8
1974	112	68	90.7	110	67	88.6	102	49	75.8	88	40	64.2	79	30	53.7	116	6-27	28	1- 3	73.6
1975	115	69	91.8	109	66	87.7	103	43	73.3	92	37	63.3	85	32	57.2	115	7-11 & 8- 4	31	1- 2, 4	72.1
1976	111	64	89.1	105	66	82.6	98	47	75.0	92	33	65.9	79	33	56.5	115	6-27 & 7-6,7	29	1- 1,2,3	72.9
1977	112	72	91.6	111	60	85.6	99	51	78.3	89	41	66.3	83	41	59.6	115	6-28 & 6-29	33	1-10	74.1
1978	111	65	91.6	107	60	84.7	105	57	79.9	89	42	63.0	75	29	53.0	116	7-19, 20	29	12- 8, 9	74.3
1979	112	69	88.7	111	70	90.0	103	47	78.0	84	34	62.3	85	37	59.0	115	6-13,27&7-10,24	31	1- 2	73.6
1980	113	65	91.1	110	63	86.6	110	48	76.6	94	38	64.9	85	40	61.4	116	7-27	38	1- 5 & 11-18	74.5
1981	116	69	93.9	107	66	88.5	96	48	73.0	90	44	66.5	81	36	59.8	116	8-27	36	12-23	75.3
1982	113	73	92.4	116	56	84.5	95	50	73.8	84	43	61.9	75	35	55.4	116	9- 2	33	1- 4	72.6
1983	111	69	89.8	112	64	89.4	96	61	77.5	90	39	64.9	76	36	58.8	114	7-12 & 13	35	1- 1, 2 & 4	74.0
1984	116	76	91.8	112	67	89.9	102	49	72.8	89	38	63.3	71	34	54.6	116	8-30	34	12-15	74.1
1985	117	68	92.1	107	58	80.9	100	54	74.3	88	36	61.2	80	33	57.1	117	8-24	28	2- 1	73.2
1986	112	74	93.7	112	58	82.0	97	54	73.5	87	42	65.0	77	33	57.0	115	7-31	33	12-12	74.9
1987	115	66	91.2	110	62	86.7	106	56	79.4	84	41	63.6	77	28	53.4	115	8-31	28	12-27	73.9
1988	109	67	90.7	109	58	85.1	105	59	80.1	96	40	64.7	83	30	55.9	111	7-25	30	12-27,30,31	73.8
1989	110	67	89.4	111	56	85.9	99	46	74.5	90	37	64.3	81	34	56.4	114	7- 4	30	2-7	74.2
1990	109	67	89.0	112	65	86.5	99	50	75.4	87	36	63.5	77	21	51.5	117	6-26	21	12-23	73.0
1991	109	71	90.9	108	63	87.1	107	43	79.8	93	39	63.8	75	33	56.0	112	7-28	31	1-30	72.8
1992	113	64	92.0	107	68	88.0	103	57	76.6	87	36	60.3	70	31	51.4	114	7-18	31	12-21	73.2
1993	118	66	90.3	112	57	85.7	105	53	76.8	87	36	61.1	76	33	54.9	118	8-1	29	1-4	73.2
1994	112	77	93.7	109	61	87.7	97	47	74.4	89	33	56.7	76	31	53.4	115	6-25	31	12-11	73.1
1995	114	69	94.0	112	62	90.3	101	50	76.3	91	45	68.4	80	37	57.7	121	7-28	37	01-18; 12-22,24	74.0
1996	112	68	91.8	107	63	84.2	106	41	74.0	87	41	63.3	78	30	56.0	115	7-31	30	12-20	73.9
1997	114	75	92.6	110	65	87.8	103	47	73.4	94	43	64.9	76	32	53.2	114	8-05	32	12-25,26,27	73.2
1998	115	67	92.6	107	59	84.8	97	45	72.1	83	40	61.6	81	28	54.4	116	7-27	28	12-23	71.4
1999	111	66	89.9	109	62	86.0	104	50	77.1	90	41	66.5	78	37	56.9	111	7-1 & 8-25	36	1-13,29 & 2-11,13	72.4
2000	112	72	92.7	111	62	86.5	100	51	73.6	79	37	58.9	81	37	58.7	113	7-18,19,24,25	35	1-8	74.4
2001	114	72	92.9	108	68	89.5	97	58	79.3	90	43	68.3	78	35	54.6	115	7-2	35	12-17, 26	75.0
2002	112	70	91.4	112	62	88.2	101	54	75.2	88	44	66.4	77	35	56.8	113	7-12	32	2-1	74.2
Average	112.5	67.3	90.8	110.0	59.7	85.5	101.4	48.4	74.7	88.8	37.4	62.8	79.8	31.9	55.5	115.2		28.9		72.7

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IMPERIAL IRRIGATION DISTRICT
WATER CONTROL SECTION
12 HOUR RUN MONTHLY TOTALS

DATE	HOLTVILLE RUNS A.M.	P.M.	CFS	EL CENTRO RUNS A.M.	P.M.	CFS	IMPERIAL RUNS A.M.	P.M.	CFS
JAN 92	237	4	918.5	95	5	431.0	70	0	250.0
FEB 92	256	6	1,013.0	111	6	551.5	76	0	301.0
MAR 92	203	8	948.0	136	10	708.5	95	3	486.0
APR 92	374	12	1,670.0	204	16	1,017.0	122	5	626.5
MAY 92	464	18	2,104.0	273	21	1,352.5	139	3	702.5
JUN 92	268	34	1,404.5	180	26	1,001.0	145	11	791.0
JUL 92	223	29	1,431.0	186	38	1,111.5	145	9	856.5
AUG 92	166	7	937.5	181	21	925.5	117	3	648.5
SEPT 92	345	26	1,529.5	240	38	1,131.0	132	2	582.0
OCT 92	712	52	2,955.5	261	26	1,088.5	168	1	672.5
NOV 92	710	30	2,906.5	216	18	931.5	160	3	628.0
DEC 92	281	16	1,248.0	97	4	402.0	66	0	270.5
TOTAL 92	4239	242	19,066.0	2180	229	10,651.5	1435	40	6,815.0
JAN 93	50	4	143.8	3	1	17.5	10	3	61.7
FEB 93	174	18	605.6	71	8	368.5	72	2	387.2
MAR 93	369	47	1,669.9	217	11	1,299.2	204	6	1,006.2
APR 93	379	28	1,726.6	296	25	1,660.8	219	8	1,161.6
MAY 93	481	34	1,989.1	301	31	1,521.3	226	17	1,351.9
JUN 93	271	29	1,213.4	251	25	1,484.4	144	10	787.2
JUL 93	177	23	1,138.8	206	14	1,149.8	146	18	1,002.4
AUG 93	165	13	903.1	179	17	981.8	134	1	756.7
SEPT 93	385	42	1,623.1	219	15	994.3	173	4	803.7
OCT 93	660	53	2,538.9	280	26	1,259.1	213	10	999.3
NOV 93	523	29	1,894.2	162	3	591.8	132	1	570.4
DEC 93	449	37	1,769.0	159	14	692.2	169	4	751.4
TOTAL 93	4083	357	17,215.5	2344	190	12,020.7	1842	84	9,639.7

DATE	BRAWLEY RUNS A.M.	P.M.	CFS	WESTMORLAND RUNS A.M.	P.M.	CFS	CALIPATRIA RUNS A.M.	P.M.	CFS	TOTAL DIVISION RUNS A.M.	P.M.	CF
JAN 92	81	0	239.0	250	8	1,043.0	201	7	790.0	934	24	3,671.
FEB 92	99	6	361.0	192	19	743.0	167	15	708.5	901	52	3,678.
MAR 92	120	15	554.5	179	11	723.0	162	12	728.5	895	59	4,148.
APR 92	155	29	823.5	229	75	1,252.0	182	16	781.0	1266	153	6,170.
MAY 92	232	18	864.0	266	57	1,189.5	208	7	868.0	1582	124	7,080.
JUN 92	144	22	757.5	100	41	620.0	112	10	601.5	949	144	5,175.
JUL 92	125	23	650.5	112	23	634.5	113	5	546.5	904	127	5,230.
AUG 92	105	10	498.5	119	18	651.5	106	17	576.5	794	76	4,238.
SEPT 92	166	5	570.5	226	42	1,120.0	183	20	725.5	1292	133	5,658.
OCT 92	273	22	1,196.0	459	32	1,895.5	298	12	1,190.5	2171	145	8,998.
NOV 92	272	4	1,202.0	406	31	1,544.0	258	7	1,013.5	2022	93	8,225.
DEC 92	99	5	377.0	140	22	556.0	135	3	588.5	818	50	3,442.
TOTAL 92	1871	159	8,094.0	2678	379	11,972.0	2125	131	9,118.5	14528	1180	65,717.
JAN 93	15	2	29.5	54	1	177.5	44	2	119.8	176	13	549.
FEB 93	56	2	169.0	134	12	495.3	141	5	455.0	649	47	2,480.
MAR 93	181	15	946.5	356	37	1,547.5	260	8	1037.4	1587	124	7.506.
APR 93	241	19	1,068.0	375	45	1,694.6	279	18	1,163.8	1789	143	8,475.
MAY 93	274	15	1,156.8	328	31	1,512.8	252	8	997.1	1862	136	8,529.
JUN 93	201	16	1,082.0	198	25	976.2	188	11	910.8	1253	116	6,454.
JUL 93	158	9	849.8	125	15	727.4	135	6	630.2	947	85	5,498.
AUG 93	146	10	727.9	166	42	964.8	136	21	712.9	926	104	5,047.
SEPT 93	245	9	841.2	339	20	1,277.2	231	6	820.2	1592	96	6,359.
OCT 93	435	17	1,655.4	751	42	2,831.4	293	30	1,173.6	2632	178	10,457.
NOV 93	292	7	1,139.6	461	12	1,624.6	216	14	780.2	1786	66	6,600.
DEC 93	167	3	689.0	356	22	1,354.4	179	7	747.0	1479	87	6,003.
TOTAL 93	2411	124	10,354.7	3643	304	15,183.7	2354	136	9,548.0	16678	1195	73,962.

copies: Mr. Flowers
Mr. Silva (2)
Mr. Dimmitt
Mr. King
Mr. Grubaugh
Ms. Clark
Mr. O'Hllaran (6)
Mr. Moore

IMPERIAL IRRIGATION DISTRICT
WATER CONTROL SECTION
12 HOUR RUN MONTHLY TOTALS

DATE	HOLTVILLE RUNS			SOUTHWEST (L) RUNS*			SOUTHWEST (M) RUNS*			BRAWLEY RUNS			WESTMORLAND RUNS			CALIPATRIA RUNS			TOTAL DIVISION RUNS		
	A.M.	P.M.	CFS	A.M.	P.M.	CFS	A.M.	P.M.	CFS	A.M.	P.M.	CFS	A.M.	P.M.	CFS	A.M.	P.M.	CFS	A.M.	P.M.	CFS
JAN 94	325	23	1,286.8	144	6	685.0	133	3	551.8	144	8	582.2	302	12	1,139.4	144	5	580.0	1192	57	4,825.2
FEB 94	280	27	1,051.0	149	11	657.2	126	2	540.0	135	5	519.2	262	19	1,006.0	168	5	703.8	1120	69	4,477.2
MAR 94	393	37	1,634.6	229	7	1,109.4	201	7	944.5	185	6	843.8	309	16	1,278.2	210	10	986.6	1527	83	6,797.1
APR 94	501	27	1,794.0	368	15	1,820.0	255	9	1,299.0	319	14	1,527.0	452	55	2,128.0	244	11	1,171.0	2139	131	9,739.0
MAY 94	619	31	2,257.2	331	16	1,591.2	225	6	1,200.6	312	11	1,303.2	364	22	1,477.2	232	16	1,112.6	2083	102	8,942.0
JUN 94	372	24	1,690.0	279	35	1,589.6	172	23	1,077.0	188	20	975.2	266	43	1,338.4	143	32	868.0	1420	177	7,538.2
JUL 94	206	18	1,318.4	266	25	1,601.7	180	12	1,183.0	196	14	1,016.7	154	38	928.5	111	21	615.9	1113	128	6,664.2
AUG 94	197	11	1,178.6	254	36	1,594.7	171	5	1,016.7	182	10	879.5	164	31	970.9	123	23	740.1	1091	116	6,380.5
SEPT 94	343	28	1,507.2	245	37	1,201.8	190	10	1,038.6	233	23	1,048.6	322	44	1,433.2	217	18	902.0	1550	160	7,131.4
OCT 94	816	61	3,349.8	347	13	1,500.4	227	5	931.8	352	22	1,427.4	644	26	2,564.6	366	12	1,304.4	2752	139	11,078.4
NOV 94	769	21	2,860.4	301	12	1,239.4	163	0	689.2	278	12	1,115.0	613	32	2,433.6	302	4	1,127.4	2426	81	9,465.0
DEC 94	477	12	1,852.6	149	5	631.4	143	4	626.0	137	3	551.6	322	12	1,335.8	149	2	588.2	1377	38	5,585.6
TOTAL 94	5298	320	21,780.6	3062	218	15,221.8	2186	86	11,098.2	2661	148	11,789.4	4174	350	18,033.8	2409	159	10,700.0	19790	1281	88,623.8
JAN 95	174	13	587.6	*Southwest (L) & (M)			113	4	378.8	58	6	196.8	203	7	687.8	92	2	282.8	640	32	2,133.8
FEB 95	375	18	1,420.4	combined 1-1-95			364	11	1,674.2	147	15	639.2	451	24	1,825.2	160	8	719.0	1497	76	6,278.0
MAR 95	473	32	1,942.4				564	21	2,667.6	237	14	1123.6	619	47	2,707.8	229	23	1163.4	2122	137	9,604.8
APR 95	542	43	2,110.4				646	40	2,984.0	218	7	1,007.0	583	52	2,455.2	296	28	1,418.4	2285	170	9,975.0
MAY 95	537	34	2,488.0				716	31	3,403.8	208	13	1,018.8	511	51	2,132.0	262	16	1,318.6	2234	145	10,361.2
JUN 95	367	30	2,041.6				606	30	3,260.3	212	27	1,120.4	322	51	1,556.0	163	27	879.4	1670	165	8,857.7
JUL 95	236	24	1,527.8				456	41	2,872.0	206	33	1,227.2	181	45	1,240.4	127	42	963.8	1206	185	7,831.2
AUG 95	227	20	1,325.6				425	47	2,622.2	176	12	921.2	217	35	1,274.4	135	14	785.4	1180	128	6,928.8
SEPT 95	438	28	1,902.6				445	42	2,154.0	233	19	1,064.4	408	39	1,796.8	261	9	1,142.4	1785	137	8,060.2
OCT 95	832	38	3,220.2				683	37	2,850.8	345	20	1,463.8	825	36	3,395.0	442	15	1,862.6	3127	146	12,792.4
NOV 95	788	16	3,027.0				470	16	1,690.4	356	5	1,301.2	670	23	2,426.4	289	15	1,134.4	2573	75	9,579.4
DEC 95																					
TOTAL 95	4989	296	21,593.6				5488	320	26,558.1	2396	171	11,083.6	4990	410	21,497.0	2456	199	11,670.2	20319	1396	92,402.5

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IMPERIAL IRRIGATION DISTRICT
WATER CONTROL SECTION
12 HOUR RUN MONTHLY TOTALS

JAN 8

DATE	HOLTVILLE AM	HOLTVILLE PM	HOLTVILLE CFS	SOUTHWEST AM	SOUTHWEST PM	SOUTHWEST CFS	NORTH AM	NORTH PM	NORTH CFS	TOTAL AM	TOTAL PM	TOTAL CFS
JAN 95	174	13	587.6	113	4	378.8	353	15	1,167.4	640	32	2,133.8
FEB 95	375	18	1,420.4	364	11	1,674.2	758	47	3,183.4	1,497	76	6,278.0
MAR 95	473	32	1,942.4	564	21	2,667.6	1,085	84	4,994.8	2,122	137	9,604.8
APR 95	542	43	2,110.4	646	40	2,984.0	1,097	87	4,880.6	2,285	170	9,975.0
MAY 95	537	34	2,488.0	716	31	3,403.8	981	80	4,469.4	2,234	145	10,361.2
JUN 95	367	30	2,041.6	606	30	3,260.3	697	105	3,555.8	1,670	165	8,857.7
JUL 95	236	24	1,527.8	456	41	2,872.0	514	120	3,431.4	1,206	185	7,831.2
AUG 95	227	20	1,325.6	425	47	2,622.2	528	61	2,981.0	1,180	128	6,928.8
SEPT 95	438	28	1,902.6	445	42	2,154.0	902	67	4,003.6	1,785	137	8,060.2
OCT 95	832	38	3,220.2	683	37	2,850.8	1,612	71	6,721.4	3,127	146	12,792.4
NOV 95	788	16	3,027.0	470	16	1,690.4	1,315	43	4,862.0	2,573	75	9,579.4
DEC 95	510	16	2,204.6	341	11	1,449.2	856	36	3,236.4	1,707	63	6,890.2
TOTAL 95	5,499	312	23,798.2	5,829	331	28,007.3	10,698	816	47,487.2	22,026	1,459	99,292.7
JAN 96	561	19	2,588.1	432	9	2,043.0	917	45	3,726.2	1,910	73	8,357.3
FEB 96	461	32	2,119.0	486	23	2,425.6	948	52	3,948.2	1,895	107	8,492.8
MAR 96	505	12	1,984.3	545	35	2,660.1	1,042	85	4,028.5	2,092	132	8,672.9
APR 96	512	41	2,333.0	672	43	3,413.8	898	186	4,256.8	2,082	270	10,003.6
MAY 96	583	52	2,373.2	639	47	3,100.8	899	107	3,639.0	2,121	206	9,113.0
JUN 96	429	27	2,160.0	558	65	3,661.4	590	91	2,786.8	1,577	183	8,608.2
JUL 96	285	39	1,812.0	463	71	3,222.6	436	84	2,514.0	1,184	194	7,548.6
AUG 96	283	67	1,841.4	438	77	2,628.8	464	55	2,421.2	1,185	199	6,891.4
SEPT 96	480	36	1,767.7	538	32	1,945.2	680	54	2,417.7	1,698	122	6,130.6
OCT 96	941	33	3,277.6	757	50	2,642.2	1,327	66	4,744.5	3,025	149	10,664.3
NOV 96	852	18	2,956.2	596	16	1,846.6	1,216	62	4,249.1	2,664	96	9,051.9
DEC 96	577	16	2,173.6	404	21	1,270.6	913	36	3,311.2	1,894	73	6,755.4
TOTAL 96	6,469	392	27,386.1	6,528	489	30,860.7	10,330	923	42,043.2	23,327	1,804	100,290.0

copies: Mr. Flowers, Mr. Moore (2), Ms. Anderholt, Mr. O'Halloran (6), Mr. Dimmitt, Mr. Mordah, Mr. King, Mr. Jones, Mr. Grubaugh

IMPERIAL IRRIGATION DISTRICT
WATER CONTROL SECTION
12 HOUR RUNS

	HOLTVILLE			SOUTHWEST			NORTH			TOTAL		
DATE	AM	PM	CFS	AM	PM	CFS	AM	PM	CFS	AM	PM	CFS
Jan-97	416	8	1,551.0	366	22	1,453.0	839	45	3,008.0	1,621	75	6,012.0
Feb-97	435	32	1,856.0	539	50	2,206.0	936	43	3,403.0	1,910	125	7,465.0
Mar-97	459	21	1,718.7	583	68	2,326.0	1,142	58	3,944.0	2,184	147	7,988.7
Apr-97	487	32	2,024.4	584	40	2,186.2	1,070	118	4,009.0	2,141	190	8,219.6
May-97	458	37	1,948.4	549	28	2,175.7	844	133	3,230.3	1,851	198	7,354.4
Jun-97	329	25	2,042.0	502	58	3,115.4	585	138	3,164.0	1,416	221	8,321.4
Jul-97	303	39	1,799.2	576	83	3,347.8	507	115	2,897.5	1,386	237	8,044.5
Aug-97	289	54	2,010.6	611	87	3,608.2	528	73	2,840.4	1,428	214	8,459.2
Sep-97	458	55	1,912.2	667	67	2,601.4	450	58	1,703.8	1,575	180	6,217.4
Oct-97	969	55	4,110.4	797	48	2,710.2	1,387	79	4,962.6	3,153	182	11,783.2
Nov-97	854	18	3,371.2	697	20	2,400.8	1,307	46	4,661.0	2,858	84	10,433.0
Dec-97	433	30	1,878.4	469	11	1,671.5	840	34	3,373.9	1,742	75	6,923.8
TOTAL 9	5,890	406	26,222.5	6,940	582	29,802.2	10,435	940	41,197.5	23,265	1,928	97,222.2
Jan-98	445	18	1,940.0	505	18	2,005.8	851	25	3,492.8	1,801	61	7,438.6
Feb-98	294	11	1,267.3	357	8	1,289.5	533	18	2,219.7	1,184	37	4,776.5
Mar-98	486	17	2,090.8	657	22	2,658.9	776	33	3,128.2	1,919	72	7,877.9
Apr-98	435	16	1,598.8	664	54	2,564.8	762	78	3,201.6	1,861	148	7,365.2
May-98	487	28	2,084.0	738	54	3,109.6	680	76	2,758.4	1,905	158	7,952.0
Jun-98	374	16	1,581.8	556	78	2,590.8	639	62	3,205.2	1,569	156	7,377.8
Jul-98	281	38	1,779.8	645	176	4,737.2	576	155	3,419.6	1,502	369	9,936.6
Aug-98	222	51	1,449.7	593	112	3,866.7	461	58	2,312.8	1,276	221	7,629.2
Sep-98	590	39	2,490.1	749	93	3,107.5	812	47	2,838.4	2,151	179	8,436.0
Oct-98	1,128	45	4,586.5	1,005	90	3,721.2	1,593	56	5,405.4	3,726	191	13,713.1
Nov-98	967	24	1,814.9	755	27	1,367.9	1,222	27	2,065.9	2,944	78	5,248.7
Dec-98	675	49	5,553.6	584	33	4,672.9	952	45	6,843.7	2,211	127	17,070.2
TOTAL 9	6,384	352	28,237.3	7,808	765	35,692.8	9,857	680	40,891.7	24,049	1,797	104,821.8

Copies: Mr. Flowers (2), Ms. Anderholt, Mr. Villalon (6), Mr. Dimmitt, Mr. King, Mr. Jones (7447 fax), Mr. Grubaugh

IMPERIAL IRRIGATION DISTRICT
WATER CONTROL DISPATCHING UNIT
12 HOUR RUNS

	HOLTVILLE			SOUTHWEST			NORTH			TOTAL		
DATE	AM	PM	CTU	AM	PM	CTU	AM	PM	CTU	AM	PM	CTU
Jan-99	519	29	1,978.1	834	26	2,935.6	621	37	2,090.4	1,974	92	7,004.1
Feb-99	524	27	1,821.2	533	43	2,270.3	753	33	2,839.4	1,810	103	6,930.9
Mar-99	594	23	1,979.9	747	42	2,605.9	967	65	3,593.7	2,308	130	8,179.5
Apr-99	539	29	1,718.1	616	61	2,391.7	840	67	3,110.7	1,995	157	7,220.5
May-99	674	29	2,117.4	727	67	2,707.3	755	86	3,007.4	2,156	182	7,832.1
Jun-99	597	35	2,495.4	644	90	3,257.1	543	115	2,709.7	1,784	240	8,462.2
Jul-99	255	34	1,522.9	490	108	3,109.6	380	146	2,474.8	1,125	288	7,107.3
Aug-99	227	26	1,233.2	471	66	2,544.8	388	55	1,828.6	1,086	147	5,606.6
Sep-99	572	22	1,883.3	574	76	2,299.9	701	57	2,552.6	1,847	155	6,735.8
Oct-99	917	30	3,035.3	1,234	57	4,296.9	801	65	2,857.4	2,952	152	10,189.6
Nov-99	946	21	3,556.4	504	25	1,922.0	1,340	40	4,677.1	2,790	86	10,155.5
Dec-99	830	33	3,276.7	587	29	2,377.4	1,309	38	4,784.8	2,726	100	10,438.9
TOTAL	7,194	338	26,617.9	7,961	690	32,718.5	9,398	804	36,526.6	24,553	1,832	95,863.0
Jan-00	548	10	1,278.4	507	22	1,147.1	1,087	23	2,092.0	2,142	55	4,517.5
Feb-00	538	13	1,340.6	567	24	1,534.2	981	36	4,629.4	2,086	73	7,504.2
Mar-00	506	30	1,207.9	684	37	1,574.8	1,054	83	2,314.6	2,244	150	5,097.3
Apr-00	483	28	1,266.0	759	49	1,842.0	955	28	2,329.0	2,197	105	5,437.0
May-00	552	46	1,287.0	860	69	2,208.0	775	145	1,936.0	2,187	260	5,431.0
Jun-00	357	45	1,251.9	729	134	2,885.6	585	184	2,116.0	1,671	363	6,253.5
Jul-00	292	51	1,321.1	682	162	3,143.3	564	127	1,980.6	1,538	340	6,445.0
Aug-00	305	63	1,277.5	523	132	2,411.2	476	144	1,640.8	1,304	339	5,329.5
Sep-00	644	51	1,850.5	699	105	1,987.2	761	94	1,797.7	2,104	250	5,635.4
Oct-00	1,298	41	3,024.8	844	84	1,953.1	1,278	74	1,628.7	3,420	199	6,606.6
Nov-00	1,191	39	2,462.2	801	53	1,790.1	1,447	43	2,854.4	3,439	135	7,106.7
Dec-00												
TOTAL	6,714	417	17,567.9	7,655	871	22,476.6	9,963	981	25,319.2	24,332	2,269	65,363.7

Copies: Ms. Anderholt, Mr. Villalon (6), Mr. King, Mr. Jones (7447 fax), Mr. Grubaugh

IMPERIAL IRRIGATION DISTRICT
WATER CONTROL DISPATCHING UNIT
12 HOUR RUNS
PROVISIONAL

	HOLTVILLE			SOUTHWEST			NORTH			TOTAL		
DATE	AM	PM	CTU	AM	PM	CTU	AM	PM	CTU	AM	PM	CTU
Jan-00	548	10	1,278.4	507	22	1,147.1	1,087	23	2,092.0	2,142	55	4,517.5
Feb-00	538	13	1,340.6	567	24	1,534.2	946	33	1,955.0	2,051	70	4,829.8
Mar-00	506	30	1,207.9	684	37	1,574.8	1,054	83	2,314.6	2,244	150	5,097.3
Apr-00	483	28	1,266.0	759	49	1,842.0	955	28	2,329.0	2,197	105	5,437.0
May-00	552	46	1,287.0	860	69	2,208.0	775	145	1,936.0	2,187	260	5,431.0
Jun-00	357	45	1,251.9	729	134	2,885.6	585	184	2,116.0	1,671	363	6,253.5
Jul-00	292	51	1,321.1	682	162	3,143.3	564	127	1,980.6	1,538	340	6,445.0
Aug-00	305	63	1,277.5	523	132	2,411.2	476	144	1,640.8	1,304	339	5,329.5
Sep-00	644	51	1,850.5	699	105	1,987.2	761	94	1,797.7	2,104	250	5,635.4
Oct-00	1,298	41	3,024.8	844	84	1,953.1	1,278	74	1,628.7	3,420	199	6,606.6
Nov-00	1,191	39	2,462.2	801	53	1,790.1	1,447	43	2,854.4	3,439	135	7,106.7
Dec-00	926	21	1,883.9	562	30	1,361.0	975	29	1,959.8	2,463	80	5,204.7
TOTAL	7,640	438	19,451.8	8,217	901	23,837.6	10,903	1,007	24,604.6	26,760	2,346	67,894.0
Jan-01	597	17	1,121.0	465	21	1,155.4	764	26	1,619.5	1,826	64	3,895.9
Feb-01	577	21	1,274.6	489	29	1,430.7	848	35	1,944.2	1,914	85	4,649.5
Mar-01	349	19	889.5	489	58	1,451.2	793	70	1,717.0	1,631	147	4,057.7
Apr-01	396	38	1,170.6	693	93	2,086.2	693	121	2,318.2	1,782	252	5,575.0
May-01	479	70	1,423.4	664	151	2,458.7	934	210	2,543.7	2,077	431	6,425.8
Jun-01	409	90	1,710.7	587	183	3,074.4	646	270	2,698.9	1,642	543	7,484.0
Jul-01	298	55	1,377.8	677	249	3,855.0	581	250	1,537.7	1,556	554	6,770.5
Aug-01	402	57	1,613.5	583	147	2,930.4	591	132	2,009.6	1,576	336	6,553.5
Sep-01	802	97	1,802.1	563	118	2,023.2	787	53	2,225.7	2,152	268	6,051.0
Oct-01	1,512	52	3,756.5	820	78	2,008.3	1,437	67	2,992.2	3,769	197	8,757.0
Nov-01	1,375	54	2,947.5	744	44	1,695.0	1,194	45	2,565.5	3,313	143	7,208.0
Dec-01	932	25	1,951.1	656	40	1,621.4	948	20	1,892.3	2,536	85	5,464.8
TOTAL	8,128	595	21,038.3	7,430	1,211	25,789.9	10,216	1,299	26,064.5	25,774	3,105	72,892.7

Copies: Ms. Anderholt, Mr. Villalon (6), Mr. King, Mr. Slyvester Jones (7447 fax), Mr. Grubaugh

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MAR - 7 2003
RESOURCE PLANNING & MANAGEMENT

IMPERIAL IRRIGATION DISTRICT
WATER CONTROL DISPATCHING UNIT
12 HOUR RUNS
PROVISIONAL
(Not Adjusted for C24 Orders)

	HOLTVILLE			SOUTHWEST			NORTH			TOTAL		
DATE	AM	PM	CTU	AM	PM	CTU	AM	PM	CTU	AM	PM	CTU*
Jan-02	711	14	1,523.2	510	34	1,347.8	781	33	1,696.0	2,002	81	4,567.0
Feb-02	611	28	1,417.9	621	58	1,845.6	835	37	2,020.4	2,067	123	5,283.9
Mar-02	509	41	1,334.6	727	75	2,063.9	953	72	2,355.2	2,189	188	5,753.7
Apr-02	350	36	1,164.6	669	84	2,145.9	915	99	2,177.0	1,934	219	5,487.5
May-02	411	45	1,359.1	666	137	2,348.6	812	92	1,907.1	1,889	274	5,614.8
Jun-02	373	48	1,430.2	604	142	2,805.6	518	156	1,838.5	1,495	346	6,074.3
Jul-02	429	56	1,830.4	500	137	2,507.7	500	123	1,756.8	1,429	316	6,094.9
Aug-02	304	45	1,388.3	570	97	2,607.4	666	143	2,184.1	1,540	285	6,179.8
Sep-02	841	54	2,490.4	787	92	2,445.0	918	93	2,006.8	2,546	239	6,942.2
Oct-02	1,561	79	4,063.8	850	64	2,163.6	1,492	67	2,998.3	3,903	210	9,225.7
Nov-02	1,279	38	2,911.3	745	57	1,776.8	1,405	43	2,783.5	3,429	138	7,471.6
Dec-02	799	20	1,712.0	475	16	1,212.6	882	19	1,839.5	2,156	55	4,764.1
TOTAL	8,178	504	22,625.8	7,724	993	25,270.5	10,677	977	25,563.2	26,579	2,474	73,459.5
Jan-03	663	28	1,548.5	515	30	1,503.0	859	28	1,942.4	2,037	86	4,994
Feb-03	312	15	801.6	360	24	1,080.3	592	28	1,340.0	1,264	67	3,222
Mar-03												
Apr-03												
May-03												
Jun-03												
Jul-03												
Aug-03												
Sep-03												
Oct-03												
Nov-03												
Dec-03												
TOTAL	975	43	2,350.1	875	54	2,583.3	1,451	56	3,282.4	3,301	153	8,215.8

***CTU = Charged to Users**

Copies: Ms. Shields, Mr. Villalon (6), Mr. King, Mr. Slyvester Jones (7447 fax), Ms. Nichols

120-166

IMPERIAL IRRIGATION DISTRICT

DELIVERY GATE WATER USE HISTORY

Resolution No. 12-96

WHEREAS, Imperial Irrigation District (IID) and San Diego County Water Authority entered into negotiations for a water transfer program that might include on-farm water conservation; and

WHEREAS, one element of an on-farm water conservation program may include voluntary allocation of water use by delivery gate based upon historical average use; and

WHEREAS, the Water Department maintains a water use record for every delivery gate; and

WHEREAS, IID needs to insure that irrigation water in excess of that considered reasonable and beneficial not be applied in order to increase the delivery gate water history base.

NOW, THEREFORE, BE IT RESOLVED that in the event that an on-farm water conservation program will include allocation of water delivery by gate, that history will not include any records of water delivery accrued after January 1, 1996.

PASSED AND ADOPTED this 28th day of May, 1996.

IMPERIAL IRRIGATION DISTRICT ORGANIZED JULY 25, 1911 EL CENTRO, CALIFORNIA

IMPERIAL IRRIGATION DISTRICT

by W. R. Condit
President

by [illegible]
Secretary

WATERUSE.RES

20-167

Elston

IMPERIAL IRRIGATION DISTRICT

OPERATING HEADQUARTERS • P. O. BOX 937 • IMPERIAL CALIFORNIA 92251

(760) 339-9751
FAX (760) 339-9009

RPM

August 23, 2001

Mr. Robert Johnson, Regional Director
US Department of the Interior
Bureau of Reclamation
Lower Colorado River Regional Office
P.O. Box 61470
Boulder City, NV 89006

Subject: Lower Colorado River Accounting System (LCRAS)

Dear ~~Mr. Johnson~~ Bob:

The Imperial Irrigation District (IID) would once again like to reiterate our dissatisfaction with the Lower Colorado River Accounting System (LCRAS). IID supports the objections voiced previously by our staff and other Colorado River contractors, most notably the Palo Verde Irrigation District.

While IID has participated in outreach workshops sponsored by your office and has offered comments and suggestions to improve LCRAS, our concerns regarding this project have not been addressed. LCRAS data and methodology continue to be revised. However, the Bureau apparently intends to replace the current decree accounting process with LCRAS for the 2001 calendar year. IID cannot support consumptive use values developed through the LCRAS process, and adamantly opposes the implementation of LCRAS at this time.

Additionally, IID has learned that outside organizations are utilizing unofficial data from existing LCRAS "demonstration" reports to further their own agendas. All information published as a result of the LCRAS process should be clearly noted as DRAFT to prevent this type of indirect legitimization. IID urges the Bureau to discourage further misuse of unofficial data and conclusions.

Once again, IID appreciates the Bureau's interest in improving the decree accounting process. However, IID cannot support the LCRAS methodologies presented to date. In our opinion this technology is still under development. Therefore, until the concerns of all Colorado River contractors are addressed, IID will not recognize consumptive use figures developed by LCRAS and will continue to utilize figures generated from the current decree accounting method. If you have any questions concerning IID's position, please contact Mr. Elston Grubaugh at (760) 339-9751.

Sincerely,

JESSE P. SILVA
General Manager

RECEIVED
AUG 27 2001
RESOURCES PLANNING
& MANAGEMENT DEPARTMENT

TAS:lh
Copy: Gerald Zimmerman, CRB

20-168

PALO VERDE IRRIGATION DISTRICT

180 WEST 14TH AVENUE — BLYTHE, CALIFORNIA 92225

TELEPHONE (760) 922-3144 — FAX (760) 922-8294

June 12, 2001

RECEIVED
JUN 18 2001
RESOURCES PLANNING
& MANAGEMENT DEPARTMENT

Mr. Robert Johnson
Regional Director
U.S.D.I., Bureau of Reclamation
Lower Colorado River Regional Office
P.O. Box 61470
Boulder City, Nev. 89006

Re: Lower Colorado River Accounting System

Dear Mr. Johnson,

P.V.I.D. has worked with your representatives on the Lower Colorado River Accounting System since the first report came out for calendar year 1995. We have carefully reviewed each report from 1995 to 1999 as to how well the process represents P.V.I.D.'s water use compared to the present decree accounting method. P.V.I.D. representatives have tried to provide constructive information to help improve the process for succeeding reports. Comments made at the March 7, 2001 workshop and Mr. William Rinne's March 24, 2000 letter to P.V.I.D., indicate that the proposed five year review period would end with the distribution of the Year 2000 Report and steps for replacing the decree accounting method with LCRAS would follow.

P.V.I.D. has tried to convey to your representatives that we have concerns that are not adequately addressed by each years modifications. P.V.I.D.'s data indicates that LCRAS is consistently under reporting our double cropped acreage and our resulting water use. We also have issues with the science used to derive the crop coefficients, unmeasured storm water runoff and tributary inflow, barren ground water use, and phreatophyte water use.

LCRAS reports are published without P.V.I.D. having any chance to review or comment on crop acreage or other data. Now other agencies are using LCRAS values without P.V.I.D. being able to provide data that would more realistically represent our water use.

We therefore are not going to acknowledge the validity of the LCRAS process as it relates to our water use. P.V.I.D. will only utilize the current decree accounting method.

If you have any questions feel free to contact myself, or staff at P.V.I.D.

Sincerely,

Charles VanDyke

Charles VanDyke, President
Board of Directors P.V.I.D.

RECEIVED
JUN 15 2001

cc: Attached List

copy: RPM staff
PVID file
LCRAS file

20-169

IMPERIAL IRRIGATION DISTRICT
OPERATING HEADQUARTERS • P O BOX 937 • IMPERIAL CALIFORNIA 92251

June 11, 1998

Mr. Robert Johnson
Regional Director
Bureau of Reclamation
P.O. Box 61470
Boulder City, NV 89006-1470

Subject: Comments - 1999 Draft *Annual Operating Plan for Colorado River Reservoirs*

Dear Mr. Johnson:

The Imperial Irrigation District (IID) appreciates being given the opportunity to comment on the May 13, 1998 draft of the *1999 Annual Operating Plan For Colorado River Reservoirs* (AOP). Your AOP recommendation to the Secretary regarding a surplus declaration signifies a critical water supply decision and is based on current reservoir storage conditions and the most recent 24-month water supply/runoff estimates which predict flood control releases the first part of 1999.

However, the expected water needs of the Lower Basin and weather patterns for 1999 and beyond should also be recognized. It is anticipated that Arizona will once again utilize its full entitlement while Lower Basin demand continues to be projected in excess of 8.0 million acre-feet. Also, recent weather forecasts by the National Oceanic and Atmospheric Administration (NOAA) indicate warming trends and drier conditions in the southwestern United States and the Colorado River Basin. This is illustrated most effectively on this agency's website (www.noaa.gov). When combined with demand, the potential for increased temperatures and reductions in precipitation during the 1999 calendar year should cause concern amongst the seven states, and the IID urges the Bureau of Reclamation to proceed with caution in its preparation of the 1999 AOP. From this perspective, it would seem appropriate for the 1999 AOP to reflect normal operating conditions until such time that actual conditions warrant a modification of the criteria from normal to surplus conditions. This course of action was used by the Bureau in 1996 and would be a more sensible recommendation for the 1999 operating criteria.

Once again, let us thank you for the opportunity to comment of the draft *1999 Annual Operating Plan for Colorado River Reservoirs* and participate in the annual consultation process.

Sincerely,

MICHAEL J. CLINTON
General Manager

cc: Gerald Zimmerman, Colorado River Board of California
Randall Peterson, BOR
Bill Rinne, BOR

20-170

COLORADO RIVER BOARD OF CALIFORNIA DATA FROM VARIOUS SOURCES

(See NOTES below tabulated values)

Calculated and Where Available, Measured Salton Sea Information

	Calculated Total Inflow (AF)	Measured Salton Sea Elevation (feet)	Salton Sea Surface Volume (AF)	Calculated Sea Salinity (mg/l)	Measured Sea Salinity (mg/l)	Calculated Flow From IID (AF/yr)	Measured Flow From IID (AF/yr)	Calculated Flow From Coachella Valley (AF/yr)	Measured Flow From Coachella Valley (AF/yr)	Calculated Flow From Mexico (AF/yr)	Measured Flow From Mexico (AF/yr)	Calculated Flow From Other sources (AF/yr)	Year	Agricultural Drain Flow From CVWD (AF/yr)
1905	4,842,387	-249.70	2,609,216			4,646,383	#N/A	45,419	#N/A	40,000	#N/A	110,585	1905	#N/A
1906	18,653,270	-199.20	15,325,218	1,073	#N/A	18,473,410	#N/A	27,392	#N/A	40,000	#N/A	112,467	1906	#N/A
1907	809,989	-201.20	14,645,982	3,422	3,353	459,984	#N/A	28,481	#N/A	40,000	#N/A	281,524	1907	#N/A
1908	303,884	-205.70	13,177,161	4,471	4,070	127,441	#N/A	25,232	#N/A	40,000	#N/A	111,211	1908	#N/A
1909	314,639	-210.30	11,757,038	5,718	5,194	132,267	#N/A	39,139	#N/A	40,000	#N/A	103,233	1909	#N/A
1910	355,612	-215.30	10,301,484	7,316	6,038	173,742	#N/A	28,919	#N/A	40,000	#N/A	112,950	1910	#N/A
1911	585,880	-219.30	9,199,515	9,165	7,180	439,921	#N/A	32,908	#N/A	40,000	#N/A	73,052	1911	#N/A
1912	620,042	-223.50	8,099,078	11,482	8,646	457,218	#N/A	32,068	#N/A	40,000	#N/A	90,756	1912	#N/A
1913	700,935	-227.70	7,053,793	13,520	10,026	543,551	#N/A	33,681	#N/A	40,000	#N/A	83,703	1913	#N/A
1914	663,094	-232.00	6,037,870	16,236	11,796	512,779	#N/A	44,284	#N/A	40,000	#N/A	66,032	1914	#N/A
1915	742,493	-237.00	4,926,899	19,458	13,774	565,406	#N/A	50,439	#N/A	40,000	#N/A	86,648	1915	#N/A
1916	938,640	-241.10	4,100,808	21,738	16,472	732,896	#N/A	50,265	#N/A	40,000	#N/A	115,479	1916	#N/A
1917	652,259	-244.30	3,509,825	26,624	#N/A	533,842	#N/A	40,056	#N/A	40,000	#N/A	38,361	1917	#N/A
1918	787,444	-248.50	2,799,463	31,483	#N/A	659,108	#N/A	47,282	#N/A	40,000	#N/A	41,054	1918	#N/A
1919	619,319	-252.00	2,259,428	35,776	#N/A	475,344	#N/A	43,013	#N/A	40,000	#N/A	60,962	1919	#N/A
1920	888,742	-248.70	2,767,377	33,416	#N/A	700,243	#N/A	45,944	#N/A	40,000	#N/A	102,555	1920	#N/A
1921	605,590	-249.00	2,719,532	34,858	#N/A	379,654	#N/A	57,253	#N/A	40,000	#N/A	128,684	1921	#N/A
1922	380,169	-249.60	2,624,863	40,421	#N/A	237,253	#N/A	48,306	#N/A	40,000	#N/A	54,610	1922	#N/A
1923	824,508	-249.00	2,719,532	38,375	37,600	670,199	#N/A	41,861	#N/A	40,000	#N/A	72,448	1923	#N/A
1924	479,345	-250.20	2,531,537	41,466	#N/A	383,178	#N/A	42,322	#N/A	40,000	#N/A	13,845	1924	#N/A
1925	548,468	-249.70	2,609,216	43,346	#N/A	405,442	#N/A	42,130	#N/A	40,000	#N/A	60,896	1925	#N/A
1926	854,811	-247.80	2,912,978	38,699	#N/A	628,819	#N/A	51,673	#N/A	40,000	#N/A	134,319	1926	#N/A
1927	834,753	-246.10	3,196,665	36,284	#N/A	643,946	#N/A	50,886	#N/A	40,000	#N/A	99,920	1927	#N/A
1928	559,987	-246.50	3,128,878	38,892	#N/A	472,687	#N/A	41,219	#N/A	40,000	#N/A	6,081	1928	#N/A
1929	899,433	-245.20	3,351,567	37,264	36,800	783,916	#N/A	40,336	#N/A	40,000	#N/A	35,181	1929	#N/A
1930	942,601	-244.30	3,509,825	36,034	#N/A	816,802	#N/A	44,380	#N/A	40,000	#N/A	41,419	1930	#N/A
1931	629,560	-244.20	3,527,620	37,431	#N/A	442,908	#N/A	41,502	#N/A	40,000	#N/A	105,150	1931	#N/A
1932	836,071	-244.00	3,563,337	36,673	#N/A	657,898	#N/A	36,174	#N/A	40,000	#N/A	101,999	1932	#N/A

COLORADO RIVER BOARD OF CALIFORNIA DATA FROM VARIOUS SOURCES

(See NOTES below tabulated values)

Calculated and Where Available, Measured Salton Sea Information

	Calculated Total Inflow (AF)	Measured Salton Sea Elevation (feet)	Salton Sea Surface Volume (AF)	Calculated Sea Salinity (mg/l)	Measured Sea Salinity (mg/l)	Calculated Flow From IID (AF/yr)	Measured Flow From IID (AF/yr)	Calculated Flow From Coachella Valley (AF/yr)	Measured Flow From Coachella Valley (AF/yr)	Calculated Flow From Mexico (AF/yr)	Measured Flow From Mexico (AF/yr)	Calculated Flow From Other sources (AF/yr)	Year	Agricultural Drain Flow From CVWD (AF/yr)
1933	534,047	-244.60	3,456,695	37,116	#N/A	408,291	#N/A	32,617	#N/A	40,000	#N/A	53,138	1933	#N/A
1934	(386,124)	-247.80	2,912,978	49,120	#N/A	(473,463)	#N/A	33,462	#N/A	40,000	#N/A	13,877	1934	#N/A
1935	560,039	-248.30	2,831,703	45,858	#N/A	375,204	#N/A	33,270	#N/A	40,000	#N/A	111,566	1935	#N/A
1936	440,641	-247.70	2,929,349	46,988	#N/A	325,068	#N/A	41,506	#N/A	40,000	#N/A	34,067	1936	#N/A
1937	667,718	-246.40	3,145,764	48,062	#N/A	556,828	#N/A	38,953	#N/A	40,000	#N/A	31,938	1937	#N/A
1938	832,971	-244.70	3,439,069	46,080	#N/A	669,887	#N/A	40,783	#N/A	40,000	#N/A	82,301	1938	#N/A
1939	925,470	-242.20	3,892,558	43,409	#N/A	670,876	#N/A	29,007	#N/A	40,000	#N/A	185,587	1939	#N/A
1940	550,539	-242.50	3,836,703	45,737	#N/A	361,701	#N/A	35,907	#N/A	40,000	#N/A	112,931	1940	#N/A
1941	1,308,072	-241.00	4,120,011	39,550	#N/A	1,080,136	#N/A	41,720	#N/A	40,000	#N/A	146,216	1941	#N/A
1942	986,878	-241.30	4,062,537	38,583	#N/A	861,988	#N/A	27,173	#N/A	40,000	#N/A	57,717	1942	#N/A
1943	1,012,116	-241.05	4,110,404	37,452	#N/A	811,186	#N/A	38,395	#N/A	57,723	57,723	104,812	1943	#N/A
1944	1,030,201	-240.80	4,158,556	37,163	#N/A	876,896	#N/A	27,637	#N/A	39,970	39,970	85,698	1944	#N/A
1945	980,803	-240.35	4,245,957	37,194	36,184	847,791	#N/A	27,660	#N/A	37,697	37,697	67,655	1945	#N/A
1946	1,129,745	-240.45	4,226,453	36,569	37,485	982,263	#N/A	29,153	#N/A	42,052	42,052	76,277	1946	#N/A
1947	857,299	-240.45	4,226,453	38,661	37,140	785,159	#N/A	24,014	#N/A	36,120	36,120	12,006	1947	#N/A
1948	1,020,051	-240.75	4,168,221	40,068	39,839	909,669	#N/A	40,678	#N/A	37,547	37,547	32,158	1948	17,700
1949	1,123,226	-240.20	4,275,299	40,218	38,453	971,880	#N/A	52,262	#N/A	44,038	44,038	55,045	1949	30,600
1950	1,146,253	-239.60	4,393,721	39,615	38,100	983,601	#N/A	110,348	#N/A	41,435	41,435	10,870	1950	89,300
1951	1,549,105	-238.30	4,656,184	36,321	38,808	1,304,718	#N/A	131,348	#N/A	36,807	36,807	76,232	1951	110,800
1952	1,613,807	-236.60	5,011,896	33,529	36,089	1,409,027	#N/A	100,595	#N/A	37,168	37,168	67,018	1952	71,700
1953	1,453,831	-235.75	5,195,227	33,083	35,158	1,329,160	#N/A	86,974	#N/A	32,424	32,424	5,272	1953	63,700
1954	1,266,818	-234.75	5,415,635	33,527	34,000	1,109,150	#N/A	104,564	#N/A	30,939	30,939	22,165	1954	78,300
1955	1,406,682	-234.35	5,504,845	33,614	33,451	1,172,491	#N/A	117,548	#N/A	48,900	48,900	67,743	1955	92,400
1956	1,160,999	-234.50	5,471,340	35,243	34,113	999,117	#N/A	79,395	#N/A	78,174	78,174	4,313	1956	52,600
1957	1,247,066	-234.45	5,482,502	35,946	34,573	994,835	#N/A	90,071	#N/A	72,607	72,607	89,553	1957	58,900
1958	1,112,280	-234.60	5,449,038	37,036	35,769	842,638	974,045	91,239	#N/A	105,974	105,974	72,429	1958	54,600
1959	1,268,797	-234.30	5,516,027	37,126	35,749	998,917	1,200,963	94,032	#N/A	123,643	123,643	52,205	1959	62,200
1960	1,422,002	-233.75	5,639,482	36,457	35,366	1,143,403	1,060,037	109,235	#N/A	123,000	123,000	46,363	1960	75,900

COLORADO RIVER BOARD OF CALIFORNIA DATA FROM VARIOUS SOURCES

(See NOTES below tabulated values)

Calculated and Where Available, Measured Salton Sea Information

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1961	1,474,819	-233.35	5,729,791	35,988	35,303	1,187,899	1,050,526	119,385	#N/A	117,000	117,000	50,535	1961	85,070
1962	1,520,951	-232.65	5,888,900	35,215	35,122	1,189,086	1,088,849	147,725	#N/A	134,000	134,000	50,139	1962	112,690
1963	1,640,458	-231.20	6,222,852	34,498	35,998	1,264,645	1,153,891	168,365	#N/A	141,000	141,000	66,449	1963	133,330
1964	1,302,352	-231.85	6,072,416	35,621	36,727	1,013,622	906,074	157,072	#N/A	106,000	106,000	25,659	1964	121,000
1965	1,322,244	-232.00	6,037,870	36,374	36,835	938,072	883,099	182,906	#N/A	113,000	113,000	88,266	1965	138,788
1966	1,314,621	-231.95	6,049,378	36,866	36,339	999,915	1,004,188	165,460	#N/A	105,000	105,000	44,247	1966	128,073
1967	1,386,820	-231.75	6,095,482	36,979	38,120	998,626	1,027,970	173,282	#N/A	98,000	98,000	116,912	1967	133,783
1968	1,321,229	-231.80	6,083,946	37,454	38,540	988,727	1,001,027	170,580	#N/A	107,000	107,000	54,922	1968	133,097
1969	1,298,350	-231.95	6,049,378	37,953	40,009	914,416	962,639	182,250	#N/A	105,000	105,000	96,684	1969	130,583
1970	1,288,714	-231.90	6,060,894	38,812	38,583	973,238	1,020,503	168,026	#N/A	101,000	101,000	46,450	1970	131,253
1971	1,464,100	-231.65	6,118,577	39,092	39,150	1,139,041	1,092,571	180,441	#N/A	109,000	109,000	35,618	1971	142,977
1972	1,429,848	-231.30	6,199,630	39,099	39,013	1,065,046	1,063,537	192,033	#N/A	113,000	113,000	59,768	1972	155,126
1973	1,502,573	-231.15	6,234,473	38,852	39,186	1,148,240	1,065,414	199,782	#N/A	119,000	119,000	35,551	1973	163,211
1974	1,579,479	-230.65	6,351,082	37,958	39,183	1,218,534	1,123,492	192,665	#N/A	113,000	113,000	55,280	1974	157,208
1975	1,523,390	-230.05	6,491,958	38,008	38,973	1,179,747	1,128,268	209,107	#N/A	101,000	101,000	33,536	1975	173,602
1976	1,560,240	-228.60	6,836,710	37,456	38,528	1,103,176	1,084,993	209,421	#N/A	104,000	104,000	143,642	1976	174,684
1977	1,424,946	-228.25	6,920,847	37,349	38,461	976,738	1,020,844	190,775	#N/A	109,000	109,000	148,433	1977	156,787
1978	1,370,258	-228.20	6,932,896	37,654	38,141	945,913	995,674	199,276	#N/A	100,000	100,000	125,068	1978	144,098
1979	1,404,761	-227.75	7,041,670	37,973	38,423	1,007,283	1,056,672	184,117	#N/A	146,000	146,000	67,361	1979	151,002
1980	1,467,981	-227.25	7,163,234	37,570	37,616	991,112	1,043,241	194,010	#N/A	158,000	158,000	124,858	1980	143,958
1981	1,278,452	-227.40	7,126,687	37,972	38,451	857,928	962,925	189,797	#N/A	158,000	158,000	72,727	1981	156,788
1982	1,336,892	-227.55	7,090,206	38,823	39,897	841,131	888,575	197,076	#N/A	159,000	159,000	139,685	1982	152,282
1983	1,417,056	-226.65	7,310,097	38,801	39,479	807,130	867,835	200,328	#N/A	245,000	245,000	164,597	1983	150,956
1984	1,416,722	-226.70	7,297,818	38,758	40,335	880,147	895,034	169,597	#N/A	268,000	268,000	98,978	1984	140,985
1985	1,389,555	-226.85	7,261,023	39,098	40,021	870,672	830,841	150,671	#N/A	260,000	260,000	108,212	1985	123,855
1986	1,268,366	-226.80	7,273,280	39,545	40,792	748,212	834,335	147,250	#N/A	265,000	265,000	107,904	1986	122,969
1987	1,293,739	-227.10	7,199,849	40,208	40,516	827,643	851,694	140,536	#N/A	251,000	251,000	74,561	1987	117,032
1988	1,355,071	-227.15	7,187,637	40,626	42,654	951,503	918,726	138,512	#N/A	227,000	227,000	38,056	1988	117,188

COLORADO RIVER BOARD OF CALIFORNIA DATA FROM VARIOUS SOURCES

(See NOTES below tabulated values)

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1989	1,287,975	-227.40	7,126,687	41,327	42,327	980,293	965,879	131,075	#N/A	155,000	155,000	21,607	1989	110,816
1990	1,357,243	-227.74	7,044,094	41,967	43,582	1,053,415	1,004,383	126,872	#N/A	135,000	135,000	41,956	1990	109,613
1991	1,418,099	-227.53	7,095,066	42,195	42,151	1,018,751	960,365	124,097	#N/A	133,000	133,000	142,251	1991	103,866
1992	1,274,278	-226.70	7,297,818	43,003	43,773	793,387	878,485	125,192	#N/A	145,000	145,000	210,699	1992	100,817
1993	1,370,908	-226.78	7,278,185	43,468	42,876	885,643	973,811	145,796	#N/A	192,000	192,000	147,469	1993	105,126
1994	1,427,190	-226.49	7,349,443	43,657	41,771	1,091,647	1,045,936	118,419	#N/A	147,000	147,000	70,124	1994	103,234
1995	1,383,098	-226.31	7,386,400	43,779	40,422	1,056,809	1,083,992	111,535	#N/A	149,995	149,995	64,759	1995	96,419
1996	1,323,827	-226.93	7,278,185	44,391	42,738	1,088,172	1,076,554	111,022	#N/A	119,755	119,755	4,879	1996	95,668

Notes:

The negative inflow from IID in 1934 reflects very dry conditions, and closure of Hoover Dam in 1933. There was undoubtedly flow from IID, but the model showed negative flow due to no reduction in assumed crop water use.

Measured flow from the Coachella Valley is shown as Not Available. There is measurement of CVWD irrigation drainage flow available beginning in 1948, (see Q55..Q103), but there is no data on surface flow, and very little data on surface storm flow available, subsurface flow, and very little data on surface storm flow available, so total measured flow from the Coachella Valley is shown as NA.

"Calculated Flow From Other Sources" is primarilly precipitation draining from lands outside of IID and CVWD, assumption = 100,000 acres times precipitation, and precipitation falling directly on the Salton Sea.

The calculated values herein were derived from the DRAFT of "The Salton Sea 1906-1996 Computed And Measured Salinities And Water Levels" by Merlin B. Tostrud of The Colorado River Board of California, November, 1997

20-171

IMPERIAL IRRIGATION DISTRICT

OPERATING HEADQUARTERS • P. O. BOX 937 • IMPERIAL CALIFORNIA 92251

March 27, 1997

Mr. John M. Ladd
Division of Water Quality
State Water Resources Control Board
P.O. Box 944213
Sacramento, CA 94244-2130

Subject: Comments: April 2, 1997 Public Hearing - Final Report on the *1996 Review of Water Quality Standards for Salinity, Colorado River System*

Dear Mr. Ladd:

The Imperial Irrigation District (IID) has examined the Final Report (consisting of both the initial and supplemental reports) on the *1996 Review of Water Quality Standards for Salinity, Colorado River System* (*Review*) and appreciates being given another opportunity to comment on this document. As the most southerly user of Colorado River waters within the United States, the IID is a primary beneficiary of Colorado River salinity control measures and sincerely supports the efforts of the Colorado River Basin Salinity Control Forum (Forum). At this time, the IID continues to endorse the existing numeric Colorado River salinity criteria and encourages the attainment of these target levels. Additionally, the IID concurs with the general recommendations set forth in the *Review*, and supports the salinity control measures the Forum has advocated to achieve current and future standards.

However, as the largest and most downstream user of Colorado River water, the IID must continue to reiterate its concerns pertaining to Colorado River salinity levels, which were submitted to the Forum in a letter dated September 3, 1996. (A copy of this letter along with the Forum's response is contained in the October 1996 Supplemental Report.) The IID and its agricultural users continue to be damaged by the Colorado River's increasing salinity, and without this program's accelerated implementation these damages will only increase. While the goal of the Colorado River Basin Salinity Control Program is ultimately a 1.48 million ton reduction in the salt loading of the Colorado River, the IID continues to feel that the pace of the current schedule (determined primarily by appropriative funding) is not adequate to obtain this objective. With this in mind, the Forum will now be recommending that Reclamation utilize cost sharing from Basin funds to supplement Federal monies. This action is a positive step towards reducing the more than $1 billion in Lower Basin damages that have been projected to occur over the next twenty years should further salinity control measures not be implemented in a timely manner.

In its response, the Forum also noted that many of the IID's concerns are related to water *supply* issues and not water *quality* issues. It is our belief that salinity concerns intertwine both of these topics, and as such this problem will not be solved by limiting the arenas in which it may be addressed. The IID is actively working with Colorado River water contractors from California as well as representatives from the other six Basin states to alleviate the supply uncertainty caused by growing Lower Basin demands, and would encourage the Forum to consider supply-oriented issues (such as the operation of the Yuma Desalting Plant) when pertinent to salinity concerns.

Once again, let us thank you for the opportunity to provide comments regarding the Final Report on the 1996 *Review*. We do so with great regard to the Forum's past accomplishments as well as their ongoing efforts to decrease salinity in the Colorado River. Again, IID concurs with the general recommendations set forth in the *Review* and encourages the State Water Resources Control Board to adopt the final Report as fulfillment of the 1996 Triennial Review. We would also encourage the State Board's support of sufficient funding so that the Forum may accomplish the objectives set forth in the *Review*.

Sincerely,

Ellen L Moore

for MICHAEL J. CLINTON
General Manager

cc: Jerry Zimmerman, CRB

20-172

IMPERIAL IRRIGATION DISTRICT
OPERATING HEADQUARTERS • P O BOX 937 • IMPERIAL CALIFORNIA 92251

March 16, 1998

Honorable Duke Cunningham
United States House of Representatives
2238 Rayburn House Office Building
Washington, D.C. 20515

Subject: Request for Increased Funding for Colorado River Basin Salinity Control Projects and Designation of Colorado River Basin as an Environmental Quality Incentives Program (EQIP) National Conservation Priority Area

Dear Congressman Cunningham:

This letter is prompted by the Imperial Irrigation District's (IID) concern for the rising salinity levels in the Colorado River Basin as well as the funding reductions that have occurred since 1994, significantly jeopardizing projects designed to combat this problem. Since the passage of the Federal Agriculture Improvement and Reform Act of 1996 (FAIRA) and the establishment of the Environmental Quality Incentives Program (EQIP), funding for salinity control projects has been merged with other programs into a single entity targeting agriculturally oriented environmental and conservation improvements. This merger has reduced the quantity of funding available for Colorado River Basin salinity control projects, resulting in increased economic damages to the entire region. The IID supports the funding recommendations of the Colorado River Basin Salinity Control Forum that are necessary to maintain quality consistent with the established standards, and requests the following FY 99 allocations towards these Colorado River Basin salinity control activities: $17,500,000 Bureau of Reclamation, $5,200,000 Bureau of Land Management, and $12,000,000 EQIP program (Department of Agriculture).

The IID, as the largest irrigation district in the nation, delivers over 2.8 million acre-feet of Colorado River water annually to over 460,000 irrigated acres in southern California. Over 97% of this water is delivered to agricultural users who have created a local farm economy nearing $1 billion annually. Salinity levels are of particular concern to these water users. Their farmland is comprised of layers of alluvial soil which when irrigated with Colorado River water, must be continually leached (to remove the salts) in order for farming to be viable. Thus salinity issues are of great consequence to the IID, who as the most southerly user of Colorado River waters within the United States, is a primary beneficiary of Colorado River Basin salinity control measures and efforts of the Colorado River Basin Salinity Control Forum (Forum).

Of particular concern to the IID are the salinity levels at Imperial Dam, which serves as the diversion point for IID and is also one of three sites on the Colorado River for which a numeric salinity criteria has been established. In June of 1996 the Forum published its *1996 Review of Water Quality Standards for Salinity, Colorado River System* (Review) which states, "there is a 18 percent chance that salinity may go above 1,000 mg/L at Imperial Dam (and) . . . the mean of 882 mg/L is above the numeric criteria level of 879 mg/L. ***This is because there is not currently enough salinity control to offset water development.***" (emphasis added) Additionally, according to IID calculations of annual salt loading in its All-American Canal conveyance facility [and as shown by the attached graph entitled *Colorado River Salinity (All-American Canal Below Drop 1)*], Colorado River salinity levels have been on an upward trend since 1984 and are nearing the Forum's 879 mg/L salinity exceedance limit. This is doubly important due to this site's proximity to the Mexican diversion point, and directly affects the United States' commitment to protect the quality of water delivered to Mexico under the 1944 Mexican Water Treaty.

Target salinity levels were designed to be met and/or maintained through the reduction of salt loading to the River from existing sources and the minimization of anticipated increases generated by future development. The goal of the Colorado River Basin Salinity Control Program is a 1.48 million-ton reduction in the salt loading of the Colorado River. However, reduced EQIP funding for these control measures has severely limited the Forum's ability to adequately address rising salinity levels. In 1995 the reduction "backlog" involved control measures that would decrease Colorado River salinity by more than 418,000 tons. This is *in addition* to future controls designed to lower the River's salt load by 437,000 tons over the next twenty years in order to meet established salinity standards. Translated to an annual basis, *there is a need for 45,000 tons of new salinity control measures to be implemented each year until 2015.* Thus, given the historical funding trends of the Program and the recent status of EQIP appropriations for the Colorado River Basin, the IID does not feel that adequate efforts are being put forth to meet this need.

The potential impact of failing to achieve targeted salinity goals in a timely manner is staggering. Damages to the Lower Basin will exceed an estimated $1 billion by 2015 if further salinity control measures are not implemented. While no recent studies have been conducted to pinpoint the true magnitude of the damages resulting from the River's increased salinity, the use of data from previous years (1976-1985) suggest an annual loss on the order of $800 million, one-third of which is thought to be agriculturally based. The damages to the IID and its agricultural community are primarily a result of lower crop yields, increased irrigation management costs, and additional drainage requirements, as well as increased water use in order to maintain a salt balance. Of perhaps even more significance though, are the problems that our irrigation district faces as a result of increasingly strict regulatory restrictions on our drain water quality. As the salinity of our inflow waters increase, we also experience a subsequent decrease in drain water quality and ultimately a degradation of the waters in the Salton Sea drainage basin. With the introduction of the Sony Bono Memorial Salton Sea Restoration Act by Senators Boxer and Feinstein as well as Speaker Gingrich and other prominent and politically diverse members of the House of Representatives, this would now appear to be a national priority

Along with many other Colorado River Basin states, agencies, and individuals, the IID believes that the restructuring of the USDA's salinity control program into the much broader Environmental Quality Incentives Program has diluted the USDA's commitment to this Basin's salinity control efforts. If this process continues to reduce funding for salinity control measures, it will only be a matter of time before numeric standards and international treaty obligations go unrealized. Combined with the damage estimates outlined earlier, these considerations provide the basis for our request of additional funding for Colorado River Basin salinity control measures and our support towards the designation of this Basin as an EQIP National Conservation Priority Area.

Thank you for allowing us to voice our concerns regarding the current status of Colorado River Basin salinity control measures. It is our hope that you will consider our comments favorably, designate the Colorado River Basin as a national conservation priority area, and increase appropriations to provide the funding necessary to meet the water quality standards which have been established to protect all Colorado River water users in the Southwest, including those in Mexico and the Imperial Valley.

Sincerely,

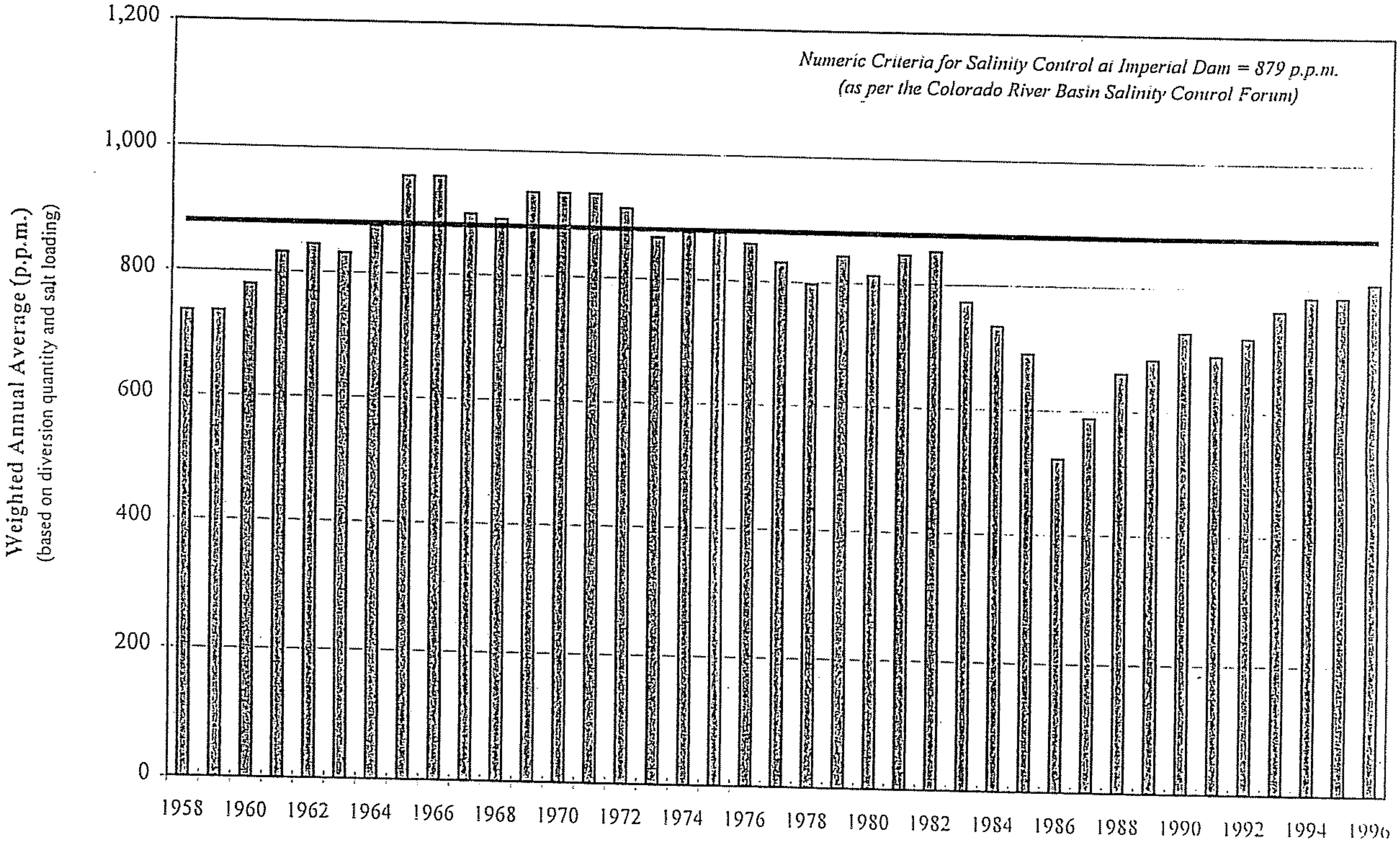
M. J. Clinton

MICHAEL J. CLINTON
General Manager

Attachment

cc: Honorable Duncan Hunter
Honorable Barbara Boxer
Honorable Dianne Feinstein
Honorable Joe Skeen
Honorable Vic Fazio
Honorable Joseph McDade
Honorable Ralph Regula
Honorable Jim Kolbe
Honorable Ron Packard
Gerald R. Zimmerman, Colorado River Board of California
Jack A. Barnett, Colorado River Basin Salinity Control Forum
Joe Raeder, The Ferguson Group
Honorable Ed Pastor
Honorable Thad Cochran
Honorable Pete Domenici
Honorable Robert Bennett
Honorable Harry Reid
Honorable Slade Gorton
Honorable Ben Nighthorse Campbell
Honorable Jon Kyl
Honorable David Skaggs

Colorado River Salinity
(All-American Canal Below Drop 1)



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WATER STRATEGIST

QUARTERLY ANALYSIS OF WATER MARKETING, FINANCE, LEGISLATION AND LITIGATION

Editors: Rodney T. Smith and Roger Vaughan

Spring 1996 Vol. 10 No. 1

Salinity of Colorado River Water: Causes, Consequences, and Remedies

Concerns about water quality have been the "forgotten stepchild" of western water. Other than the infrequent court case involving substantial degradation of water quality, such as from wholesale dumping of mine tailings in rivers making water virtually unsuitable for use, western water law has mostly focused on the allocation of the available quantity of water.

So matters stood until the advent of federal and state water quality regulation. Virtually every river and stream in the western states either confronts today or will soon confront water quality issues. How well considerations of water quality are integrated with the administration of water rights will determine how effectively western water resources are managed.

In this article, *WS* examines one dimension of water quality (salinity) in a major river system, the Colorado River Basin. Salinity has a major adverse economic impact, especially on local agricultural economies. Over the past two decades, state and federal policy has attempted to control the salinity of Colorado River water through projects and programs targeted at changing the methods of use of Colorado River water, especially in the Upper Basin. Less emphasis has been placed on the beneficial impact of the amount of water in reservoir storage and the size of river flows, even though these factors have a greater impact on actual salinity levels than salinity control projects.

With the economic stakes in salinity control growing in tandem with the march of salinity levels back to historically-high levels, the causes, consequences, and remedies for Colorado River water salinity promise to become critical policy issues. When the debate blossoms, anticipate greater emphasis on economic incentives in selecting salinity control projects and stricter scrutiny of proposed changes in reservoir operations. Especially for agricultural communities, they will find at stake the foundations of their local economies.

In This Issue . . .

"Salinity of Colorado River Water" examines the causes, consequences, and remedies of salinity. With the march of salinity levels to historically-high levels, anticipate greater emphasis on economic incentives in selecting salinity control projects and stricter scrutiny of reservoir operations as attention is turned to the beneficial impact of reservoir storage and river flows. Especially for agricultural communities, they will find the foundations of their local economies threatened by proposed changes in reservoir operations.

"Finance Annual Report for 1995" reports on the bond market results from the $4 billion in new money and the $1 billion in refinancings raised in 1995.

"Finance Update" reviews the results from the 112 issues that raised $2.2 billion in the first quarter of 1996 and examines six proposed state finance bills.

"Legislative Update" describes the 60 state bills tracked by *WS* this year.

"Litigation Update" discusses a U.S. district court decision upholding the award of punitive damages for landowners who suffered from groundwater contamination.

"Transaction Update" discusses 26 transactions tracked by *WS* in the first quarter of 1996. CBT prices were above $1,600/unit, with two of the seven transactions above $1,700/unit.

BACKGROUND

The mainstem of the Colorado River provides municipal and industrial water for more than 18 million people and irrigation water to 1.7 million acres in the United States, as well as 1.5 million acre feet of annual water supplies for agricultural and municipal uses in the Republic of Mexico. The salinity of Colorado River water has become a significant policy issue — the Bureau of Reclamation estimates that the annual economic losses in the United States from Colorado River water salinity now approach $1 billion. Therefore, the future salinity of Colorado River water will have a significant impact on the economies dependent on Colorado River water.

Nearly half of the salinity in Colorado River water is from natural sources, such as saline springs, erosion of saline geologic formations, and runoff. The remaining sources reflect water development that adds salts to the Colorado River or

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Salinity of Colorado River Water

continued from page 1

reduces the amount of water available for dilution. Irrigated agriculture accounts for 37% of salinity by consuming water and by dissolving salts (found in the underlying saline soils and geologic formations) which are then included in return flows to the Colorado River. The evaporative losses of reservoirs account for 12% of salinity (evaporation results in the same salt load diluted by a smaller quantity of stored water). Municipal and industrial users only account for 3% of salinity, because of their relatively small diversions and low salt concentrations in return flows.

The efforts to control the salinity of Colorado River water started with the passage of the Water Quality Act of 1965, which required states to adopt water quality criteria for interstate waters inside their boundaries. In 1972, the seven Colorado River Basin states (Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming) agreed to a policy of maintaining salinity concentrations in the Lower Colorado River System (Arizona, California, Nevada) at or below then existing levels, while the other Upper Basin states developed their compact apportionments of Colorado River water. After the U.S. Environmental Protection Agency required development of numerical salinity standards, the Basin States founded the Colorado River Basin Salinity Control Forum to develop quality standards, numerical criteria, and a basinwide salinity control plan.

The water quality standards seek to maintain flow-weighted averages of total dissolved concentrations at or below specified levels at three locations in the Lower Basin (mg/L = milligrams per liter):

Hoover Dam .... 723 mg/L
Parker Dam .... 747 mg/L
Imperial Dam .... 870 mg/L

The standard requires that salinity levels do not increase (from 1972 levels) due to the estimated impact of future water development. The goal for salinity control projects is to remove the same amount of salt load from the Colorado River that is generated by additional water development. Because of the large variability in natural salinity levels, actual salinity levels may be considerably higher or lower than the criteria in any given year.

Congress has passed legislation to implement the salinity control plan. The Colorado River Basin Salinity Control Act of 1974 authorized construction of 4 control units and planning of 12 control projects above Imperial Dam (which is near the border with Mexico). The projects included installation of wells to intercept brine from saline groundwater and improvements in conveyance systems to reduce the amount of groundwater percolating through saline soils before it reaches the Colorado River. In 1984, Congress amended the Salinity Control Act to authorize a U.S. Department of Agriculture (USDA) program. The program provides, among other activities, financial and technical assistance to land users to plan, install, and maintain salinity reduction practices, such as conversion of irrigation systems to sprinklers and improvement of off-farm laterals. Such projects reduce the amount of water that flows through saline soils as return flows and thereby reduce the amount of salts deposited into the Colorado River.

Based on estimates by the Department of the Interior, these salinity control projects pass a cost-benefit test. The economic benefits from salinity control are estimated at $340 per ton of salt removed. The cost of salinity control projects generally ranges between $20 to $100 per ton of salt removed.

HYDROLOGY AND SALINITY

The salinity of Colorado River water is extremely sensitive to the amount of water flowing through the Colorado River system. Runoff and reservoir storage are key factors in determining actual salinity levels. Because these factors vary radically with hydrologic conditions, salinity levels are driven more by hydrology and reservoir operations than by salinity control projects.

Consider the historic salinity levels in the Lower Basin (see Chart, p. 5). Levels at all three locations remained below 700 mg/L until the mid-1950s. Salinity levels then increased by approximately 200 mg/L during the period of low Colorado River flows in the mid-1950s, then fell considerably with the high river-flow years in the late 1950s. Salinity levels then marched upward until they reached their peaks in the early 1970s (when numerical criteria for water quality standards were set). Salinity levels then began a sustained decline after the early 1970s, rapidly plummeting during the 1983-86 period of historic flooding on the Colorado River, which purged significant amounts of salt from reservoirs and further reduced salinity through dilution. At the time of the flooding, Reclamation anticipated that this improvement in salinity would persist for several years. However, this expectation was not fulfilled when flows on the Colorado River after 1986 proved to be below normal. Since the late 1980s, salinity levels have steadily increased.

WS documented the critical importance of reservoir operations and hydrologic conditions in determining salinity levels. A statistical study related salinity levels to:

- the river flows at each location during the current and preceding two years
- the amount of water stored in Lake Mead at the end of the preceding water year

These factors explain about 90% of the historic variation in salinity levels at each location, showing that the wide variation in salinity levels closely tracks the variation in water storage and river flows. Each 1 million acre foot (MAF) increase in water stored at Lake Mead <u>reduces</u> salinity by 10.7 mg/L below Hoover Dam and by 8.0 mg/L at Parker Dam and Imperial Dam (see Chart 2, p. 5). Each 1 MAF increase in the three-year average flows at Hoover Dam or Parker Dam <u>reduces</u> salinity by

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Salinity of Colorado River Water

. . . *continued from page 2*

about 6 mg/L. The impact of river flows on the salinity of Colorado River water at Imperial Dam is almost three-fold the impact at Hoover Dam and Parker Dam.

In contrast to the impact of reservoir storage and river flows, the impact of salinity control projects — though beneficial — is relatively small. In its 1995 report *Quality of Water Colorado River Basin*, the Department of the Interior estimated that the salinity control units completed or under construction by Reclamation, USDA, and the Bureau of Land Management will potentially remove 934,680 tons of salt annually, which is on the order of 10% of the annual salt load of the Colorado River at Hoover Dam. That is, with full implementation of the salinity control projects, the salinity of the Colorado River would be on the order of 66 mg/L less than it otherwise would have been. While this reduction generates significant economic benefits for the Colorado River Basin, it is relatively small in comparison to the wide fluctuations in salinity created by changes in water storage at Lake Mead and in river flows.

ECONOMIC LOSSES FROM SALINITY

Salinity imposes economic losses on users of Colorado River water. For agricultural water users, salinity reduces crop yields. For households, salinity corrodes water pipes, hot water heaters, and other appliances, and requires users to engage in treatment to improve water quality. For water and waste water utilities, salinity reduces the useful life of facilities and equipment as well as reducing the yield from water reclamation projects. For industry, salinity requires investment in treatment facilities to keep levels below the thresholds needed to maintain industrial operations or to meet permissible levels for discharged water. A 1988 Bureau of Reclamation study concluded that, for the salinity levels prevailing during 1976-85, these economic losses totaled $311 million annually (1986 dollars), with the losses distributed as follows: households (50%), agriculture (36%), water and wastewater utilities (11%), and municipal and industrial users (3%).

In 1995, Reclamation stated that annual basinwide economic losses are related to the salinity levels at Imperial Dam as follows:

Salinity Level mg/L	*Basinwide Economic Loss ($ Millions)*	*Incremental Loss per 100 mg/L*
500	0	0
784	500	176
879	1,000	526

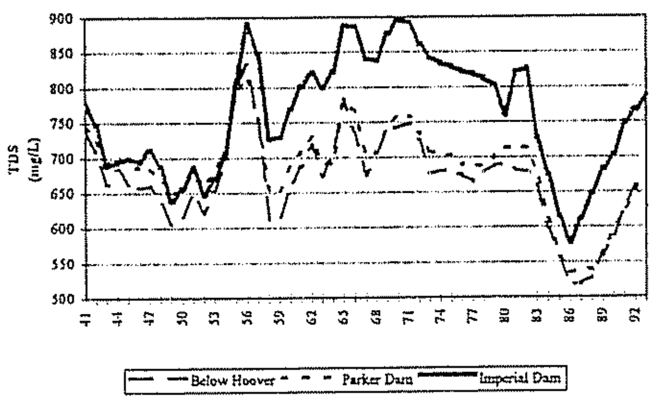
The incremental loss from increased salinity is *three* times greater if the initial level of salinity is greater than 784 mg/L than if it is less than 784 mg/L.

While aggregate economic losses from salinity in the Colorado River Basin are significant, the aggregate data obscure the significant loss sustained by agricultural communities. There are two reasons. First, Reclamation data only measure the loss from reduced crop yields, but not the economic losses from any induced land retirements. (Reclamation recognizes the losses from land retirement, but lacks a basis to project their magnitude.) Second, the measured losses are not put within the context of the economic base of agricultural communities.

WS illustrates the importance of these considerations with a case study of the impact of increased salinity of Colorado River water on the local economy of Imperial County, California, the largest user of Colorado River water. Consider the impact of a 100 mg/L increase in salinity on the four major crops (alfalfa hay, carrots, lettuce, onions) that Reclamation included in its study of salinity losses. The gross value of these crops accounts for the majority of gross value of all vegetables and field crops grown in Imperial County.

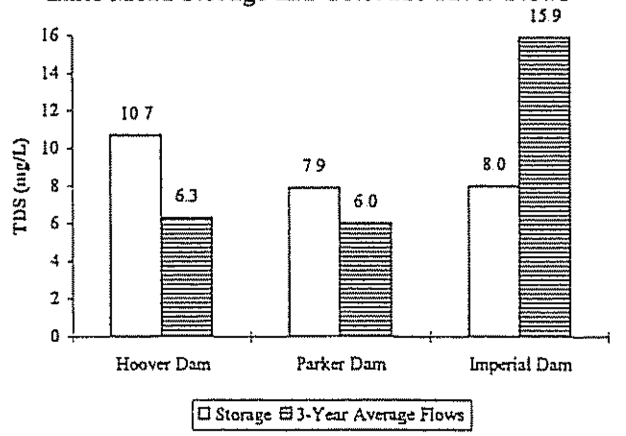
There are three major, adverse impacts of increased salinity on the local economy. First, the lower crop yields reduce the net income earned in farming: $72/acre for alfalfa

Chart 1
Historic Salinity Levels in the Lower Basin



Source: Department of Interior Quality of Water, Colorado River Basin, 1995

Chart 2
Reduction in Salinity from 1 MAF Increase in Lake Mead Storage and Colorado River Flows



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Salinity of Colorado River Water

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hay, $601/acre for carrots, $233/acre for lettuce, and $124/acre for onions (see Table 1) Second, these economic losses will be magnified as growers and landowners (to the extent that lower yields reduce land rents) have less income to spend on local goods and services. Third, since the income losses represent significant reductions in the economic return of crops (*e.g.*, grower income plus land rents) some of the lands will be retired — the per acre income losses are 42% of the per acre economic return for alfalfa hay, 33% for carrots, 25% for lettuce, and 9% for onions. Land retirements will have an adverse impact on the local economy, both directly with the decline in incomes for growers and landowners and indirectly as growers, landowners, and other individuals in farm-related jobs have less money to spend on local goods and services

The full impact of increased salinity will depend on the magnitude of land retirement (see Table 2). If no land is retired, the direct and indirect economic losses total $29 million, or approximately 10% of the total contribution of these four crops to the local economy. Assuming that the pattern of land retirement reflects the relative loss of economic returns, the total economic loss would approach $48 million annually if 10% of the irrigated lands in the four crops is retired and about $67 million if 20% of the irrigated lands in the four crops is retired. These impacts range from one-tenth to one-fourth of the total economic contributions of these crops to the local economy of Imperial County.

REMEDIES

All users of Colorado River water have a significant stake in maintaining, if not reducing salinity levels. The keys to success will be greater reliance on economic incentives in identifying salinity control projects and recognizing the beneficial impacts of river flows and water storage at Lake Mead when determining reservoir operations.

Salinity Control Projects As part of this year's farm bill, Congress included the Colorado River Basin Salinity Control Program in a new Environmental Quality Incentives Program (EQIP) administered by USDA. The law reflects the view that voluntary, incentive-driven programs will accomplish more than regulatory programs. The Secretary of Agriculture has initiated rulemaking for implementing regulations. The most effective way to achieve the law's intent (maximization of environmental benefit per dollar expended) would be to accept the cheapest voluntary bids to remove salt until USDA's appropriation for salinity control is exhausted

Unfortunately, Congress limited the potential of a voluntary program to achieve the law's intent when it generally limited incentive payments to 75% of estimated project costs. A simple example illustrates the problem. Assume that growers A and B can remove 100 tons of salt at costs, respectively, of $50/ton and $80/ton. The law limits the eligible incentive payments to growers A and B, respectively, to $37.50/ton and $60/ton. Suppose that the other economic benefits from the projects (improvement in agricultural operations and/or market value of conserved water) are lower for grower A than grower B. Therefore, grower A will undertake his project only if he receives $40/ton (greater than the 75% limit), while grower B will undertake his project if he receives $55/ton (less than the statutory limit). With the statutory restriction, only grower B can undertake his project. Unfortunately, the federal government must spend 37.5% more ($55/ton versus $40/ton) to reduce the salt load by 100 tons.

Reservoir Operations. The beneficial impact of river flows and water storage on salinity has been ignored by proponents of proposed changes in reservoir operations at Lake Mead, which would have a surplus declared in the Lower Basin until storage in Lake Mead declines by about 9 MAF.

A 9 MAF drawdown of Lake Mead would permanently increase salinity in the Lower Basin by 96 mg/L below Hoover Dam and by 72 mg/L at Parker and Imperial Dams. This increase would more than offset the impact from all salinity control projects currently completed or under construction. Based on Reclamation's estimate of the incremental economic losses from increased salinity, the annual, basinwide economic losses from the proposed draw down of water stored in Lake Mead would be $380 million.

Proponents of changed reservoir operations propose to

Table 1
Impact of 100 mg/L Increase in Salinity on Crop Yields in Imperial County

Crop	*Acres*	*Yield Loss*	*Loss/Acre*	*Economic Return per Acre*
Alfalfa Hay	175,023	9.4%	$72	$171
Carrots	15,361	9.6%	$601	$1,826
Lettuce	22,982	6.3%	$233	$924
Onions	11,268	2.4%	$124	$1,315

Notes: Average acreage for 1993-95. Yield loss based on empirical relation between crop yields and salinity at Imperial Dam. Loss per acre based on yield loss and average crop values for 1993-95. Economic return equal to estimated growers income and land rents.
Sources: Imperial County Agricultural and Livestock Reports for acreage, yields, and crop values. Crop Budgets prepared by Cooperative Extension, University of California for data on grower incomes and land rents

Table 2
Impact of 100 mg/L Increase in Salinity on Imperial Co. Economy

Land Retirement	*Annual Loss of County Income ($Millions)*	*% of Contribution of Local Economy*
0%	29	10
10%	48	17
20%	67	23

Notes: Loss of county income includes direct and indirect impact of reduced crop yields and land retirement. Contribution of local economy equals the direct and indirect impact of crop activity on local economy. Estimates based on IMPLAN regional input/output model for Imperial County draw down Lake Mead in anticipation of the next period of flooding on the Colorado River. During the last 100-year flood in the early 1980s, they observe, deliveries of mainstem Colorado River water to Mexico in excess of U.S. treaty obligations totaled 55 MAF. Remarkably, these flows are characterized as "wasted" even though these flows significantly reduced annual salinity levels in the Lower Basin during the 1983-88 period by about 50 mg/L below Hoover Dam and Parker Dam and by 125 mg/L at Imperial Dam. These reductions avoided economic losses totaling $2.4 billion.

Finally, any beneficial impacts from the temporary increase in river flows from a declaration of surplus will be minor in comparison to the detrimental impact on salinity levels from reduced storage at Lake Mead. A declaration of surplus, of course, would only increase river flows below Hoover Dam and at Parker Dam because the surplus water would be used by municipal water users in the Lower Basin. Salinity levels would fall by 6 mg/L for each 1 MAF increase in the three-year average flows at these locations. However, to increase three-year average flows by 1 MAF, a total a 3 MAF must be released from Lake Mead. Therefore, this reduction of storage in Lake Mead would permanently increase salinity by 32.1 mg/L below Hoover Dam and by 23.7 mg/L at Parker Dam, while the greater river flows would only temporarily reduce salinity levels by 6 mg/L at these locations. As already described, salinity levels at Imperial Dam would be permanently increased without any temporary salinity reduction due to increased river flows.

CONCLUSION

Controversy over water quality will soon take a place alongside traditional controversies over the quantity of water. As federal policy continues its "reinvention" toward the use of economic incentives, salinity control projects will turn to market mechanisms. While the passage of the Environmental Quality Incentives Program this year can be an important step, Congress limited the scope for success by adhering to cost-based pricing schemes rather than relying on economic incentives created by voluntary transactions. Salinity control policy seems destined to recreate the debate water conservation and transfer policy has had over cost-based versus market-based compensation. Look for the pace of actual salt load reductions under the Environmental Quality Incentives Program to match the slow pace of the actual conservation and transfer of water.

The real potential salinity "train wreck" on the horizon involves proposed changes in reservoir operations. By ignoring the beneficial impact of river flows and water storage, proponents advocate a course of action that will inevitably and significantly increase the salinity of Colorado River water. For agricultural communities, these proposals put at risk the foundations of their local economies. □

Annual Bond Market Review

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Table 3
Twenty Largest Water Issues 1995

Issuer	Amount ($mil)	Security Type	Issue	Lead Underwriter
San Diego Public Facs Fin Auth	350.0	Rev	Neg	Morgan Stanley
CA Dept of Water Resources	335.0	Rev	Comp	Lehman Brothers
Houston-Texas	201.0	Rev	Comp	Chemical Securities Inc
East Bay MUD	200.0	Rev	Neg	Morgan Stanley
So California Metro Water Dt.	175.0	Rev	Comp	Paine Webber-Subsidiary
Nevada	128.8	Go	Comp	Goldman Sachs
San Diego County Water Auth	110.0	Rev	Neg	Lehman Brothers
King Co-Washington	100.0	Rev	Neg	J P Morgan
Brownsville-Texas	94.0	Rev	Neg	Goldman Sachs
Fresno-California	91.1	Rev	Neg	J P Morgan
Lower Neches Val Auth ID Corp	86.0	Rev	Neg	Goldman Sachs
San Jose-St Clara W Fin Auth	81.1	Rev	Neg	Morgan Stanley
Rio Rancho-New Mexico	80.0	Rev	Neg	Rauscher Pierce Refsnes
Santa Fe-New Mexico	78.0	Rev	Neg	Rauscher Pierce Refsnes
CA Dept of Water Resources	76.0	Rev	Neg	Goldman Sachs
Ca Dept of Water Resources	76.0	Rev	Neg	J P Morgan
So California MWD	70.0	Rev	Neg	Morgan Stanley
Bexar MWD	68.0	Rev	Neg	Smith Barney Harris Upham
So California Metro Water Dt.	60.0	Rev	Neg	Morgan Stanley
Tulsa Metro Utility Authority OK	60.0	Rev	Neg	Lehman Brothers

Source: Compiled by *Stratecon, Inc* from *Securities Data Co* data

UNDERWRITING WESTERN WATER

First place on the *WS* Underwriter Top 10 for 1995 throughout the West was Morgan Stanley, capturing 16 percent of the market with 6 issues that raised $804.6 million. Morgan's strength lies in California where it was responsible for underwriting 5 of the state's largest issues. It displaced Smith Barney Harris from the top position: SBH fell to ninth — with 14 issues raising $208.8 million.

Lehman was second with $559.7 million in 8 issues, including 3 of the top twenty issues — two in California and one in Oklahoma. Paine Webber, last year's second, fell to fifth. Goldman Sachs was third, underwriting $494.98 million in 8 issues, including large issues in Nevada, California, and Texas.

Merrill Lynch Capital Markets slipped from last year's third place to fourth this year. The company underwrote 19 issues — but none among the top 20 — raising $411.8 million and giving them an 8.2 percent market share. As was true last year, the relatively low overall market shares of the top underwriters are a mark of how competitive water underwriting has become — the major factor in driving down spreads.

As usual, the busiest underwriter was Rauscher Pierce Refsnes with 41 issues, raising $395.4 million, putting them at No. 6 on the overall list (up one position from last year).

WS expects water bond markets to accelerate during 1996 — pushed by lower rates and by the unexpectedly vigorous economic and fiscal recovery in California. □

20-174

IMPERIAL IRRIGATION DISTRICT

OPERATING HEADQUARTERS • P. O. BOX 937 • IMPERIAL, CALIFORNIA 92251

September 3, 1996

Mr. Jack A. Barnett
Executive Director
Colorado River Basin Salinity Control Forum
106 West 500 South, Suite 101
Bountiful, Utah 84010

Subject: Comments-*1996 Review of Water Quality Standards for Salinity, Colorado River System*

Dear ~~Mr. Barnett~~: Jack —

The Imperial Irrigation District (IID) has examined the *1996 Review of Water Quality Standards for Salinity, Colorado River System* (*Review*), dated June 1996, and appreciates being given the opportunity to comment on this document. As the most southerly user of Colorado River waters within the United States, the IID is a primary beneficiary of Colorado River salinity control measures and sincerely supports the efforts of the Colorado River Basin Salinity Control Forum (Forum). The IID concurs with the general recommendations set forth in this *Review*, and supports the salinity control measures the Forum has advocated to achieve current and future standards. At this time, the IID also continues to endorse the existing numeric Colorado River salinity criteria and encourages the attainment of these target levels.

However, as the largest and most downstream user of Colorado River waters in both California and the Lower Basin, it is imperative to the IID that the salinity control programs noted in this *Review* not only be implemented, but placed on an accelerated schedule as well. The IID and its agricultural users continue to be damaged due to the increasing salinity of the Colorado River, both by economic losses and the requirement to use more water to sustain an acceptable salt balance. If the current scheduling of planned projects is not expedited, the likelihood of failing to meet targeted salinity standards becomes not only a danger, but a reality. According to this *Review*, when existing *observed* salinity levels are adjusted to reflect the full impact of the current level of water development within the basin (long-term mean water supply), these *adjusted* salinity concentrations exceed the Forum's numeric criteria at all three measurement stations. Of particular concern to the IID are the salinity levels at Imperial Dam (IID's point of diversion), but we obviously have a vested interest in water quality at the two upstream stations as well.

While the goal of the Colorado River Basin Salinity Control Program (Program) is ultimately a 1.48 million ton reduction in the salt loading of the Colorado River, the IID does not feel that the pace of the current schedule is adequate to obtain this objective. In fact, based on the analysis outlined in this *Review*, the 1995 Program "backlog" involves controls that would reduce Colorado River salinity by more than 418,000 tons. This is in addition to future controls designed to lower the River's salt load by 437,000 tons over the next twenty years. Thus, according to the *Review*, this translates to a need for "45,000 tons of new salinity control measures . . each year . . . (until) 2015." Given the current status and recent funding trends of the Program, the IID does not feel that adequate efforts are being put forth to implement additional salinity control projects. The tables that provide exceedance evaluation analyses for the three measurement stations in the *Review* further illustrate this point. The text in Appendix C notes that, with only the existing salinity controls in place, "there is a (sic) 18 percent chance that salinity may go above 1,000 mg/L at Imperial Dam (and) . . . the mean of 882 mg/L is above the numeric criteria level of 879 mg/L. *This is because there is not <u>currently</u> enough salinity control to offset water development.*" (emphasis added) These figures provide the basis and impetus for the IID's request for an accelerated Program implementation schedule. The Review also notes that, based on available data, "the measured salinity will not exceed the numeric criteria during the next three years". The IID disagrees with this conclusion. The Program allows for temporary increases due to the completion of additional water development projects provided "appropriate control measures" are planned, even if they are not implemented at the time of development. However, the District does not feel that appropriate funding and/or scheduling currently exists to implement these controls.

The potential impact of the Program's failure to achieve targeted goals in a timely manner is staggering. Damages to the Lower Basin will exceed an estimated $1 billion by 2015 if further salinity control measures are not implemented. The damages to the IID and its agricultural community are briefly documented in the *Review*, and are primarily a result of lower crop yields, increased irrigation management costs, and additional drainage requirements, as well as increased water use required to maintain a salt balance. Also touched upon, and of perhaps even more significance, are the problems that our irrigation district faces as a result of increasingly strict regulatory restrictions on our drain water quality. As the salinity of our inflow waters increase, we also experience a subsequent decrease in drain water quality and ultimately a degradation in the waters of the Salton Sea drainage basin.

While no recent studies have been conducted to pinpoint the true magnitude of the damages resulting from the River's increased salinity, the use of data from previous years (1976-1985) would indicate an annual loss on the order of $700 million (one-third of which is thought to be agriculturally-based). Due to the age of this data, there also appears to be an urgent need to update this information for the 1986 to 1995 time period in order to develop a more accurate and current estimate of the potential economic impacts resulting from increased salinity levels.

As noted in this *Review*, federal funding has been reduced in recent years (since 1994). Combined with the Program's transition to a basin-wide planning approach, it appears to the IID that the Program is not only off-course, but slowing to a pace that will cause irrevocable harm and economic damage to the IID, its water users, and its surrounding communities. The IID is thankful that the Colorado River Basin's hydrology has been favorable since the Program has gotten off-track, but this can only mitigate the effects of salinity for so long.

It is with great regard to the Forum's past efforts and accomplishments that the IID requests the acceleration of planned salinity control projects and the update of the 1988 Bureau of Reclamation report analyzing the estimated economic impacts of Colorado River salinity. We are well aware of the funding restrictions and difficulties that most public agencies are facing in the current economy, and sincerely appreciate all of the Forum's achievements to date. It is however, in our consumer's best interest to actively promote and encourage the timely attainment of the Forum's targeted salinity goals. Once again, let us thank you for the opportunity to comment on the 1996 *Review* and voice both our support and concern for the existing Program.

Sincerely,

M. J. Clinton

Michael J. Clinton
General Manager

20-175

7

Economic Evaluation of Irrigation with Saline Water Within the Framework of a Farm, Methodology and Empirical Findings: A Case Study of Imperial Valley, California

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Introduction

The Imperial Valley of California is located in the southeast corner of the state, bounded on the south by Mexico and on the east by Arizona. The sole water supply for the Valley is diverted from the Colorado River by the Imperial Irrigation District (IID), which delivers this water by gravity flow to approximately 475,000 acres of land. In 1973, the gross value of crop production in the Valley was $296.7 million, making it one of the most productive areas in the nation.

Resource Base

Irrigation water from the Colorado River has shown a trend toward higher salt levels ever since irrigation development commenced at the turn of this century. Figure 1 shows this trend over the past 30 years and the projections made for the future by the Colorado River Board (1970). These data indicate a current salinity level of about 950 ppm of total dissolved solids or an electrical conductivity (EC) of 1,500 μmho. The Colorado River Board (1970) projects the salinity of the River to rise to 1,210 ppm by the year 1990 if anticipated upstream developments are made and if sources of salts entering the River are not removed or other mitigating investments made.

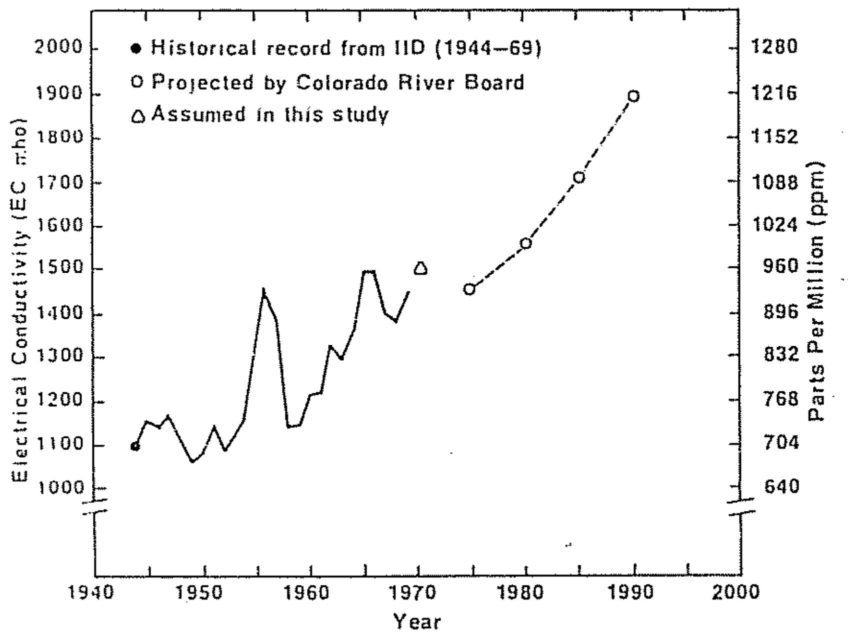

Fig. 1 Historical record and projected trend of water salinity in the Imperial Valley.

The long-term average water supply to the Valley has been more than adequate for intense agricultural production. The 20-year average deliveries per acre for the period 1948-1967 was 4.66 acre feet/year of 14,200 m^3/ha.

The soils of the Imperial Valley are composed of alluvial deposits of fine-textured clays, silts, and fine sands deposited by floodwaters of the Colorado River and coarse-textured wind-transported materials. Both materials occur in strata and lenses of different textures and in various combinations. Crop productivity and drainage practices are influenced by the particular textural combinations encountered in localized areas. Using the local terminology, 71% of the Valley's soils are classified "heavy," that is, clays; 17% "medium," that is, loams and fine sandy loams; and 12% "light," that is, loamy very fine sand and loamy fine sand.

The climate of the Imperial Valley can be characterized as arid, with an average annual rainfall of 2.85 in. (72.4 mm). Most of this scant rainfall occurs in the months of December, January, and February. Hot summers and mild winter temperatures allow year-around farming operations.

Table 1 Number of Farms[a]

Year	1-99	100-219	220-499 (acres)	500-999	1,000+	Total
1950	1,178	362	306	177	108	2,131
1960	603	218	208	155	122	1,306
1974[b]	374	103	112	91	150	830

[a]From Census of Agriculture, U.S. Department of Commerce.
[b]Estimated from preliminary data.

Farm Size Distribution

As elsewhere in California and the United States, the average size of farms in the Imperial Valley has been increasing over time. The data in Table 1 indicate that the number of farms with less than 1,000 acres of land has been decreasing and those over 1,000 acres have been increasing. If we assume that farms of less than 100 acres are part-time or hobby farms, it appears that commercial farms are nearly uniform in distribution with respect to size.

Necessary and Sufficient Conditions for a Long-Term Irrigated Agriculture

Salinization or salts in soils is an extremely important problem in irrigated arid regions of the world. Productive soils may be salinized at different rates, depending on the amount and composition of dissolved salts imported with the irrigation water. Bernstein (1967) considers three factors or conditions affecting water quality determinations—salt tolerance of crops, soil permeability, and drainage.

Because of the physical conditions of climate, soil permeability, drainage (natural or artificial), and the salt tolerance of the crops adaptable to a specific location, irrigation water of a given quality may or may not be usable. These limitations are not absolute, and there is a degree of substitutability among them. For example, artificial tile drainage can be substituted for natural drainage, or the quantity of water can be substituted for quality of water through the use of a higher leaching fraction. Also, crops with a higher salt tolerance can be used to replace salt-sensitive crops as the quality of water deteriorates. In the concept of a long-run steady state, these physical factors can be used to described the limitations to the possibility of a long-term irrigated agriculture. That is, the physical factors determine the necessary conditions for a long-term irrigated agriculture, but they do not specify the sufficient conditions.

The sufficient conditions are specified by the economic parameters that influence the economic viability or irrigated farms. Assume a present-value profit equation in the form

$$\pi_{pv} = \sum_j B_i \left(\sum_i P_{ij}Y_{ij} - \sum_k C_{ikj}X_{ikj}\right) \tag{1}$$

where $Y_{ij} = f^*(X_{ikj})$ and $k=1, \ldots, s$, and where B_j is the discount factor, P_j is price of the i^{th} commodity and Y_i is its level of output, and C_k is the unit cost of the $X_k{}^{th}$ factor input in the i^{th} commodity and the j^{th} year.

By use of the calculus, the optimum use rate for each resource in each time period can be determined. However, the profit equation was constrained so that income in any subplanning period does not become negative. The subplanning period can exceed one year, but cannot be so long that resources with critical zones with respect to, say, salinity in the root zone passes some irreversible level.

The objectives of this chapter are (1) to report the methodology and empirical results of generating a farm firm production function where the return to land and water is a function of both quantity and quality of the water supply; and (2) to estimate a farm firm demand schedule for irrigation water with varying supply and quality levels.

Effects of Supply and Quality of Irrigation Water on Individual Crops*

Assume a production function for an individual irrigated crop of the form

$$y = g(w_q, w_i|K, L, R, \ldots) \tag{2}$$

where y is yield per acre (hectare), w_q is the water supply variable measured in inches or centimeters, w_i is the quality of the irrigation water supply measured in terms of its electroconductivity, and K, L, and R are capital, labor, and rainfall, respectively.

Following an earlier study (Moore, 1961), we assume that relative plant growth is a function of the mean moisture stress in the root zone of the plant. Then the index of crop growth for one irrigation cycle can be stated as

$$I_{\theta_i} = \frac{\int_0^{\theta_i} g(m)dm}{\theta_i \cdot 100} \quad m = (0, \ldots, i) \tag{3}$$

*The author acknowledges that portions of the following section were taken from Moore et al (1974) with the permission of the copyright holder, the American Geophysical Union, publishers of *Water Resources Research*.

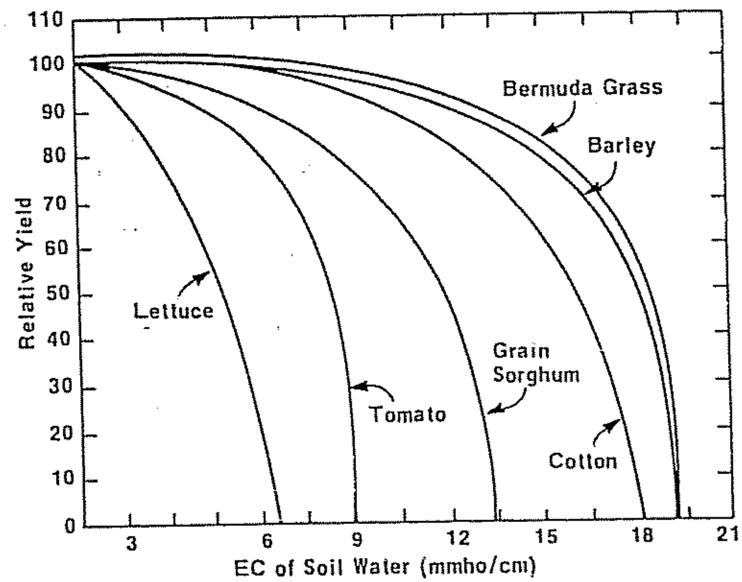

Fig. 2 Salt tolerance of selected crops.

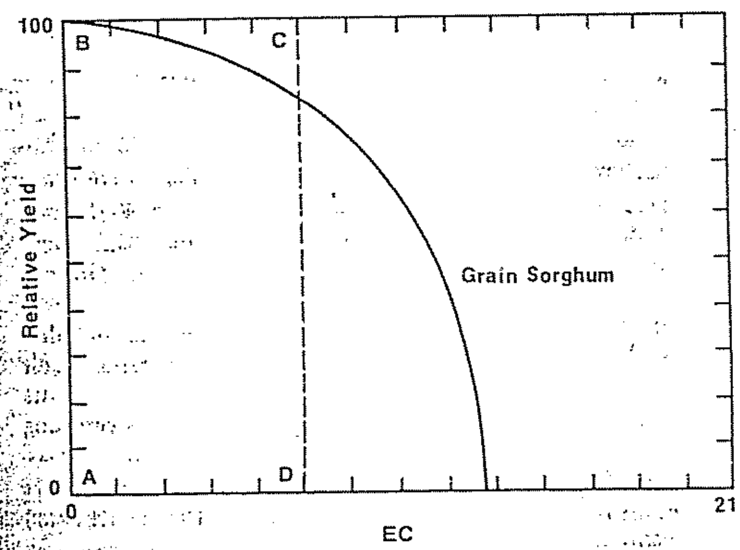

Fig. 3 Salt tolerance growth relation.

where I is the growth rate for one irrigation cycle, θ_i is the soil moisture depletion percent at the time of a subsequent reirrigation, and g(m) is the functional relation between plant growth and soil moisture stress.

The variable w_i in Eq. (2) represents the quality dimension of the irrigation water input. Results of studies by the U.S. Salinity Laboratory at Riverside, California (Bernstein, 1967) indicate that most plants respond negatively to increases in soil salinity.† Representative growth-response curves relating crop yield to the electroconductivity of the soil saturation extract are presented in Fig. 2. The growth index, $I_{\theta j}$, which represents one of these curves for one irrigation cycle, can be defined as the definite integral of a specific growth curve as a fraction of the rectangle ABCD in Fig. 3. This can be expressed as

$$I_{\theta_j} = \frac{\int_0^{\theta} jf(s)\,ds}{\theta_j \cdot 100} \tag{4}$$

where θ_j is the electroconductivity of the saturation extract at the time of a reirrigation and f(s) is the functional relationship between plant growth and soil salinity.

We can combine Eqs. (3) and (4) into Eq. (5):

$$I_{\theta_{ij}} = \frac{\int_0^{\theta_i} \int_0^{\theta} jf(m, s)\,dm\,ds}{(\theta_i)(\theta_j)(100)} \tag{5}$$

Using this theoretical production response relation, 36 possible combinations of irrigation treatment, water quality level, and leaching fraction for each of three soil types and for each crop were budgeted (see Sun, 1972 for additional details of this procedure). Production efficiency frontiers were drawn using these budgets (see Fig. 4A) showing the locus of the budgeted points using the highest physical yield per unit of water as the efficiency criteria. Only those budgeted combinations falling on the efficiency frontier were considered for further analysis.

In the example for cotton in Fig. 4A, yield declines in response to additional units of irrigation water applied. Increased salinity in the irrigation water also has a negative effect on yields. As the electrical conductivity (EC) of the irrigation water increases (quality decreases), yield is reduced but at a decreasing rate.

There is a trade-off or substitutability between water quality and water quantity. This is shown by the isoquants in Fig. 4B. Figure 4B was constructed

† See also Chap. 3.

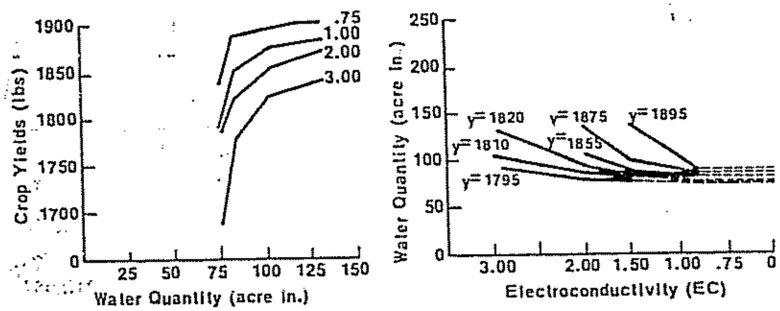

Fig. 4 Efficiency frontiers and production isoquants of cotton in medium soil.

from the data in Fig. 4A and indicates that in order to obtain the same yield of cotton, a larger and larger quantity of water must be applied as the EC of the water increases. Note the increasing distance between isoquants as the EC increases.

Model of the Farm Firm

In order to estimate the effects of different levels of water quality and water supply, a linear programming model was constructed. As was done in developing the efficiency frontiers, cost and return budgets were constructed for each point on the efficiency frontier for each of nine alternative field crops. Three separate models representing three farm sizes were constructed.

Because of the long-term planning horizon under consideration, the objective function for the linear programming model was written to maximize the return to land and water that would be equivalent to maximizing returns for one subplanning period in Eq. (1). This allowed us to take into consideration changes in land values as water quality declined over the planning period.

The objective function was maximized subject to the constraints of a limit to the total quantity of water available based on water rights on the Colorado River, and a seasonal peak water supply based on the physical capacity of the canal system. The supply of land was divided into three soil types. A restriction was placed on the model that lettuce acreage could not exceed 10% of the total irrigated acreage on a farm because of the sensitivity of lettuce prices assumed to a significant increase in winter lettuce production. The acreage of sugar beets that could be grown was limited to 12.5% of the irrigable land for nematode control. Based on historic data, a constraint of 9% of irrigable crop land was placed on cotton acreage because of the cotton allotment program that was in effect at the time of the study. Also because of federal production control

Table 2 Annual Return to Water and Land, Four Water Qualities by Farm Size[a]

Farm size	Water quality (EC) 0.75	1.50	2.00	3.00
Small	$ 40,854 (113.8)	$ 35,888 (100.0)	$ 30,687 (85.5)	$ 25,492 (71.0)
Medium	$ 93,309 (112.0)	$ 83,316 (100.0)	$ 72,823 (87.4)	$ 61,448 (73.8)
Large	$317,348 (112.0)	$283,882 (100.0)	$249,068 (87.7)	$210,054 (74.0)

[a]Figures in parentheses indicates index of income with current condition = 100.

programs then in effect, a constraint that at least 30% of the land must be planted to alfalfa or remain fallow was imposed on the model.

Effect of Water Quality on Return to Water and Land

Table 2 summarizes the results of the linear programming model for four levels of water quality and three farm sizes in the Imperial Valley.

Net returns may be expected to decrease by 12 to 15% from the current level if and when the salinity level of the lower Colorado River declines to an EC of 2.0 from the current EC of 1.5. This level (2.0) is projected for the year 2000. In the unlikely event that the salinity level were to increase to an EC of 3.0, a 26 to 29% reduction in farm net returns to land and water could be expected. A level of salinity of this magnitude is far beyond anything anticipated in the future and must be considered a very-low-probability event.

On the other hand, if by dilution or desalination it was possible to reduce the salinity level in the lower Colorado River to an EC of 0.75, that is, half the current level, net returns would increase 12 to 14% above their current level.

Changes in net returns may be explained by changes in total crop acreage, changes in the proportion of high-valued/salt-sensitive crops, adjustments in the leaching fraction, and the irrigation regime that is followed.

Changes in total crop acreage were a major factor influencing returns to water and land was water quality changed. The data in Table 3 indicate that both the amount of double cropping and total crop acreage declines as salinity levels in the lower Colorado River increase and that this pattern holds for all farm sizes.

Changes in the crop mix grown also have important effects on the return to land and water as salinity levels increase. The data in Table 4 indicate that

Table 3. Estimated Total Crop Acreage and Double Cropping for Four Levels of Water Quality by Farm Size, Imperial Valley

Farm size	Item	Water quality (EC) 0.75	1.50	2.00	3.0
Small	Total acreage	387.4	379.0	366.1	359.5
	Crop percent[a]	121.1	118.5	114.4	112.3
Medium	Total acreage	774.8	758.3	732.9	732.3
	Crop percent	121.0	118.3	114.5	114.4
Large	Total acreage	2,612.8	2,516.7	2,435.0	2,433.1
	Crop percent	123.0	118.5	114.6	114.5

[a](Total crop acreage/irrigable acreage) X 100.

Table 4 Crop Acreage for Four Levels of Water Quality by Farm Size, Imperial Valley

Crop	Farm size	Water quality level (EC) 0.75	1.50 (acres)	2.00	3.00
Alfalfa	Small	8.2	–	–	–
	Medium	16.5	–	–	–
	Large	96.1	–	–	–
Barley	Small	123.9	123.9	123.9	155.1
	Medium	247.8	247.8	222.4	310.3
	Large	822.2	822.2	740.5	946.1
Cotton	Small	28.8	28.8	28.8	28.8
	Medium	57.5	57.5	57.5	57.5
	Large	191.0	191.0	191.0	191.0
Grain sorghum	Small	123.9	123.9	110.9	135.6
	Medium	247.8	247.8	222.4	284.3
	Large	822.2	822.2	740.5	946.0
Early grain sorghum	Small	31.2	31.2	31.2	–
	Medium	62.5	62.5	87.8	–
	Large	207.5	207.5	289.2	83.7
Lettuce	Small	312.	31.2	31.2	–
	Medium	62.5	62.5	62.5	–
	Large	207.5	207.5	207.5	–
Sugar beets	Small	40.1	40.1	40.1	40.1
	Medium	80.2	80.2	80.2	80.2
	Large	266.3	266.3	266.3	266.3

under our assumptions, alfalfa, which is salt-sensitive at the germination stage, is profitable only at the higher water quality levels (EC = 0.75). The normative solution indicates that land should be left fallow at higher salinity levels. Other than alfalfa, little change occurs in the optimum crop mix until salinity levels reach EC 3.0 (a level far above projections for the lower Colorado River). If salinity levels ever reach thus high level, lettuce (a salt-sensitive crop) would no longer be produced and a large decrease in the acreage of early planted grain sorghum would occur.

The remaining crops—barley, cotton, and sugar beets—are tolerant to moderately tolerant to salts, and little or no change is observed in their acreage except the modest increase in barley acreage at the highest salinity level.

In this study, the initial objective function was to maximize the return to land and water. In order to separate out the return going to land and the return going to water, certain assumptions were made: (1) The current average cash rent per acre of land was a valid estimate of the marginal value product (MVP) of the land resource. (2) As water quality declined, the MVP of land would decline

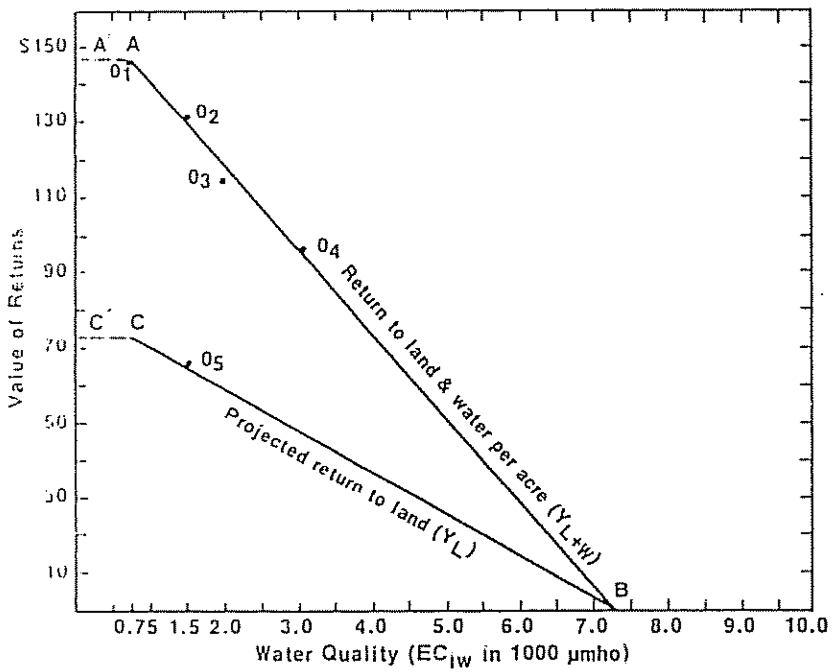

Fig. 5 Projection of return to land and return to water of varying water qualities in the Imperial Valley.

until it reached zero at a water quality level at which farm income also became zero. Stated another way, we made the assumption of "no crop – no land rent." (3) A linear interpolation between these two points would trace the path of land rents as water quality declined. (4) At water qualities higher than the current level, land rent would increase at the same rate to a point where the EC of the irrigation water was equal to 0.75 and no increases would be expected after that. The results of these assumptions are displayed in Fig. 5.

In Fig. 5, the results of the above assumptions are displayed graphically. The return to land and water (Y_{L+W}) is plotted freehand through the points 0_1, EC = 0.75, 0_2, EC = 1.50, 0_3, EC = 2.0, and 0_4, EC = 3.0. Extrapolation to the horizontal axis indicates a point B at EC = 7.25 where the return to land and water is zero. Separation of the return to land (Y_L) alone is made following these assumptions, where point 0_5 is the current cash rent per acre under existing water quality conditions and is projected to intersect the horizontal axis at EC = 7.25 (the assumption of no water—no land rent).

Technical economies of farm size are present in the Imperial Valley, and if these economies are imputed to the irrigation water input, they become reflected in higher returns to this resource as farm size increases. The data in Table 5 reflect the results of separating out the projected land rent under varying conditions of water quality and the effect of farm size on the return to water based on our assumptions.

Table 5 Average Return to Water for Four Water Quality Levels, by Farm Size, Imperial Valley

Item	Farm size	Water quality (EC) 0.75	1.50	2.00	3.00
		(dollars)			
Return to land & water per acre	Small	127.67	112.15	95.90	79.66
	Medium	145.80	130.18	113.79	96.01
	Large	149.34	133.59	117.21	98.85
Estimated land rent		73.50	65.00	59.00	48.00
Return to water per acre	Small	54.17	47.15	36.90	31.66
	Medium	72.30	65.18	54.79	50.85
	Large	75.84	68.59	58.21	50.85
Return per acre foot	Small	9.95	8.66	6.78	5.81
	Medium	13.28	11.97	10.06	8.82
	Large	13.93	12.60	10.69	9.34

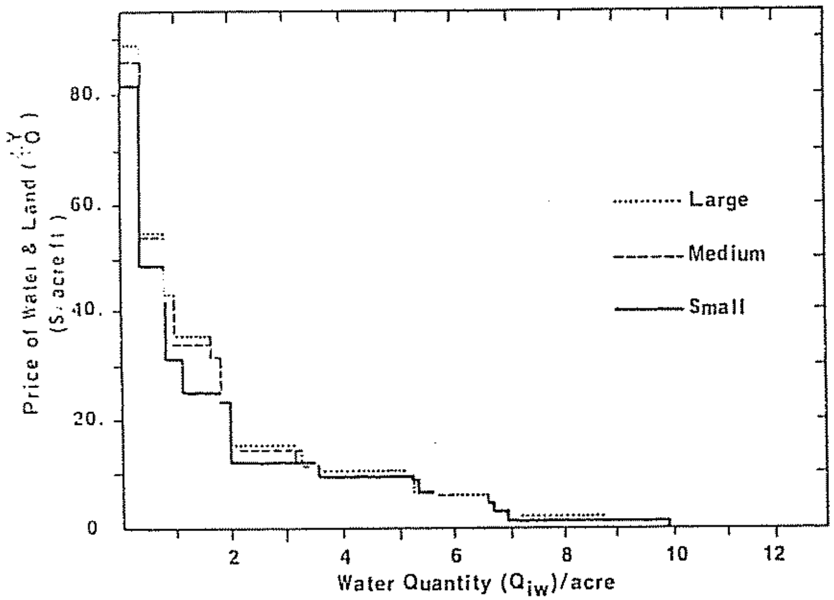

Fig. 6 Price of water and land relative to farm size, with current water quality (EC_{iw} = 1.5).

Demand for Irrigation Water

The linear programming model may be utilized to obtain a static-normative derived demand function for irrigation water. By parametrizing the price of water over the relevant range of prices to the farm, price-quantity relations can be traced. The data shown in Fig. 6 display these relations for the three sizes of farm under consideration in terms of acre feet per acre of irrigable land as opposed to the traditional practice of determining the total quantity of water used. By calculating demand on an acre feet per acre basis, differences in water use by dissimilar-sized farms can be compared directly. These data, estimated for the current water quality level of EC = 1.5, indicate only minor differences between farm sizes in the net return to land and water. This result is not surprising in that the technology and feasible cropping alternatives are virtually the same for all commercial farms in the Imperial Valley. Returns to land and water for the small farm are somewhat below those of the two larger farm sizes, primarily because of the economies of size discussed above.

The effect of water quality on the individual farm demand for irrigation water is equally as dramatic as the price effect. The return to land and water for four levels of water quality for the three prototype farms is shown in Table 6. These data indicate, for an EC of 1.5 (the current situation in the lower

Table 6 Marginal Return to Land and Water for Three Water Supply Levels by Farm Size and Water Quality Level

Water supply per acre	Farm size	Water quality level (EC) 0.75	1.50	2.00	3.00
		(dollars)			
1.61 acre ft	Small	27.83	25.00	23.39	10.87
	Medium	37.69	34.29	32.25	11.39
	Large	39.28	35.88	33.93	11.94
5.45 acre ft	Small	9.00	6.60	8.68	7.54
	Medium	8.99	6.60	9.92	9.36
	Large	9.52	6.60	10.26	9.77
8.0 acre ft	Small	2.06	1.75	1.97	2.06
	Medium	2.71	1.74	1.80	2.06
	Large	2.72	2.08	1.80	2.06

Colorado River), the return for three specific points on the water supply axis of Fig. 6. Second, reading horizontally, at very limited water supply levels the effect on the return to land and water is very pronounced. For example, on the large farm the marginal return to land and water at EC = 0.75 and a water supply of 1.1 acre feet/acre is $39.28/acre and declines to $11.94 when EC increases to 3.0.

The effect of increasing salinity declines as irrigation water supplies become more abundant. At a water supply of 8.0 f/acre (which is greater than the current entitlement of the district), the water quality effect is much smaller. For the large farm, the marginal return to land and water for an EC of 0.75 is $2.72/acre f and declines to about $2.06/acre f with a water quality level of EC = 3.0

Summary and Conclusions

In this chapter, we have attempted to analyze the effect on individual farm changes in the quality and quantity dimension of the water supply using a case study of the Imperial Valley of California.

Utilizing the knowledge available at this time (estimates could be improved as additional information is made available through research in plant soil moisture-salinity relationships), we have developed a production function for irrigated crops where water quantity and water quality are independent variables. As was expected, crop response to additional water applied exhibits diminishing marginal returns. Declining water quality (increasing salinity levels) has a negative effect on yield. It was shown that the negative effects of salinity can be offset by substituting additional units of water. In other words, there exists, at least to a limited extent, a trade-off between water quantity and water quality.

With irrigation technology fixed at the current level of technology, as the water quality in the Imperial Valley decreases from the 1970 level of EC = 1.5 to its projected level of EC = 2.0 by about the year 2000, net returns to land and water in the Valley will be expected to decrease by 12 to 15%. If the quality of the water in the lower Colorado River continues to deteriorate beyond the year 2000 level, to, say, EC = 3.0, farm incomes will be proportionately lower, threatening the economic viability of the Valley's agricultural sector.

Operators of larger-sized farms will be in a better position to survive economically under either conditions of severe limitations on the supply of water available or high salinity levels. This result follows primarily from the economies of large-scale farming that can be imputed to the residual return to land and water.

Fruitful areas for future research include improvement in the estimation of the production function based on empirical field test plots where soil moisture tension, electrical conductivity, and leaching fractions are experimental variables. Second, increased knowledge of alternative irrigation technology, including flood, furrow, sprinkler, and drip irrigation application, will become increasingly important. Third, better methods of estimating field drawdown curves with artificial drainage and the effect of water table levels on plant-soil moisture-salinity relationships need to be developed.

We have attempted to show the economic implication of a production response surface. As knowledge is gained in this area, we shall be able to place increased confidence on the analytical results.

References

Bernstein, L. (1967). *Salt Tolerance of Plants*, U.S. Dept.Agr. Bull. 217, 21 pp.

Colorado River Board of California (1970). *Need for Controlling Salinity of the Colorado River*, Resources Agency, State of California.

Moore, C. V. (1961). A general analytical framework for estimating the production function for crops using irrigation, J. Farm Econ. *43*(4); 876-888.

Moore, C. V., Snyder, J. H., Sun, P. (1974). Effects of Colorado River water quality and supply on irrigated agriculture, Water Resources Res. *10*(2).

Sun, P. C. (1972). An economic analysis of the effects of quality and quantity of irrigation water on agricultural production in Imperial Valley, California. Unpublished Ph.D. thesis, Department of Agricultural Economics, University of California, Davis, Calif.

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Physical and Economic Evaluation of Irrigation Return Flow and Salinity on a Farm

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Introduction

The physical and economic problems in water application, return flow, and reuse present a difficult challenge to users and policy makers. The conflicts that develop have been treated with little proficiency because of lack of information on the basic elements of the problem.

The physical aspects of the problem arise because of natural sources and irrigation return flow, which constitute a large portion of the water in streams and rivers of many parts of the world. In some river basins, such as the Colorado in the United States, some water may be used for irrigation several times before the little that remains enters the ocean or other repository. Since this use involves the evapotranspiration process, which accounts for the major water loss by crops, there is an inevitable buildup of salt concentration in irrigation return flows. In some cases, salt deposits are leached from the soil. Thus, both concentration of the water and loading of the stream may occur. This is seen in the salinity of the Colorado River, which ranges from less than 50 mg/liter (total dissolved solids) in the upper basin mountains to about 850 mg/liter at the Imperial Dam in the lower basin. Even though irrigation return flow may be involved in only part of the salinity concentration, it has been suggested as one of the major areas capable of management. Management of irrigation water to influence downstream salinity has not been considered extensively in the past and, therefore, little is known about the manifold effects of such management.

The economic conflict is generated because the well-being of some users of a river usually conflicts with the well-being of others. There is no solution that

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Salinity, Drainage, and ET Issues in the Imperial Valley

A Partial Status Report of Current Opinions
and Future Research Needs

Made to
Imperial Irrigation District

by

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Foreward

The answers to two technical on-farm irrigation questions are important for IID (a) in determining the need for reasonable and beneficial use of water, and (b) for estimates of how much water may be available for future water transfer. The two questions are:

1. How much water is needed for salt control?
2. What are the unstressed evapotranspiration (ET) requirements of crops?

This report does not answer those questions satisfactorily, because there are many gray areas in current knowledge. However, it does bring many gray areas to light and does conclude with some estimates regarding salt control needs.

This report should be considered as a basis for further dialog. The conclusions are based upon the author's experience, plus interpretation of literature and limited field data.

When reports such as this are read by interested parties, new facts and interpretations come to light. It is hoped that those revelations can be brought forward in a positive and constructive forum to achieve a consensus and arrive at a better understanding of these technical issues.

Introduction

IID is currently faced with challenges and opportunities regarding improved on-farm water management and water conservation. Of particular concern is the question of "How much water is needed for reasonable and beneficial use in on-farm irrigation?"

"Beneficial use" includes (Burt, 1990):

1. ETAW. Applied irrigation water used for evapotranspiration (ET).
2. LR. Leaching Requirement. The fraction of applied water necessary for adequate leaching to maintain a desired soil salinity. The LR concept does not account for non-uniformity of irrigation.
3. Water for special cultural practices (eg., weed germination, climate control).

"Reasonable use" recognizes that an irrigation efficiency (with no under-irrigation) will always be less than 100%. Irrigation Efficiency (IE) is defined as:

$$IE = \frac{\text{Irrigation Water Beneficially Used}}{\text{Irrigation Water Applied}} \times 100$$

It is impossible to apply irrigation water with 100% irrigation efficiency without reducing crop yields. All irrigation systems have inherent non-uniformity of water application across a field; "good" Distribution Uniformities (DU) in most of California are accepted to be 75 - 80%.

$$DU = \frac{\text{Minimum infiltrated in a field}}{\text{Average infiltrated in a field}} \times 100$$

With no under-irrigation in a field, and neglecting Leaching Requirement (LR), a DU of 80% means that about 20% of the infiltrated water is destined to deep percolation below the root zone (ie, drainage water). Many Imperial Valley soils have unique sealing characteristics (Robinson, 1980; Grismer, 1986) which, combined with the predominate surface irrigation methods within IID, may enable IID farmers to have higher DU's (eg., about 90%) than farmers in other areas of California.

"Reasonable use" of water recognizes the need for "beneficially used" water, plus the extra water used in non-uniformity, evaporation, inevitable poor timing, and (sometimes) tailwater runoff. What constitutes "reasonable use" varies with time and location, and must account for economic, social, agronomic, human, and other factors. What is reasonable today may be considered unreasonable in 20 years in the future.

Tailwater runoff has been and continues to be an important item in efficiency discussions in IID. However, this report does provide answers to the tailwater questions.

A list of questions which must be addressed in defining the future IID water needs in the "reasonable and beneficial use" categories. The major sub-categories are:

1. Beneficial Use.
   a. ETAW. Crop Evapotranspiration. Studies of IID water use have often targeted estimated ET for a single year and used those values in projecting future needs. Future needs have considerable uncertainties. Even present ET requirements of specific crops are uncertain. Researchers commonly acknowledge that the ET estimation techniques are only accurate within plus or minus 10% without extensive field verification.

      Even if the present ET requirements were known precisely, there are factors which may cause the ET to increase in future years. Those factors include:

      1. Reduced salinity stress due to better salt management.
      2. Elimination of poor yield spots on fields.
      3. Reduction of scald on alfalfa.
      4. Reduction of other disease problems.
      5. Improvement of irrigation DU.
         - Reduced root pruning.
         - Minimizing under-irrigation at some points in the field.
      6. Improved soil fertility.
      7. Crop mix change.
      8. Global warming, resulting in higher temperatures.
      9. Tighter drain spacing, contributing to a healthier root zone.
      10. Controlled traffic farming to reduce machinery compaction (eg., row alfalfa instead of border strip).
      11. More frequent irrigations.

b. LR. Leaching Requirement. The following items have been identified as possible reasons to increase estimates of how much deep percolation is needed:

1. Preferential flow of water during infiltration into soils. Some of the water which deep percolates moves through large cracks and is not effective for leaching.
2. High temperature adjustment of salt tolerance values.
3. Increasing salinity of Colorado River water in future years.
4. Consideration of DU. Many discussions of IID salinity problems have neglected the importance of DU, and assume that all points in the field receive the same amount of water.
5. Consideration of LR in light of crop rotations on fields. The LR should be based upon the most salt sensitive crop grown in a field during a rotation, rather than the crop presently planted on that field.
6. Development of new techniques to facilitate more leaching. On many soils in IID, with the present farming and irrigation practices, large amounts of leaching water will damage the crops (due to poor aeration and drowning). New practices such as drip irrigation, sprinkler irrigation, row alfalfa, tighter drain spacing, and mole drains, may enhance the ability of farmers to adequately leach salts from the soil.

2. Reasonable Use.

a. Deep percolation due to non-uniformity. As IID farmers develop new farming/irrigation techniques, they may be able to eliminate under-irrigation. This will result in more deep percolation due to non-uniformity, as illustrated in the figure below.

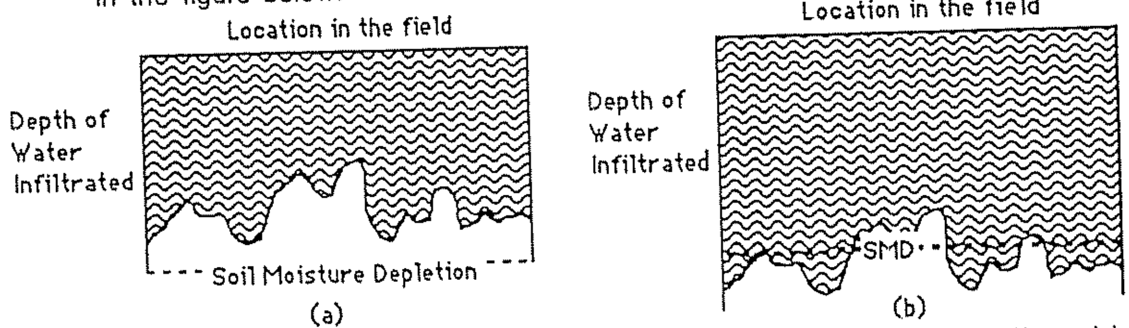

Figure 1. Deep percolation caused by non-uniformity (DU) of irrigation, as affected by under-irrigation. Both (a) and (b) have non-uniformity. However, since (a) is completely under-irrigated, the DU does not contribute to deep percolation. As the under-irrigation is reduced (b), deep percolation due to non-uniformity appears.

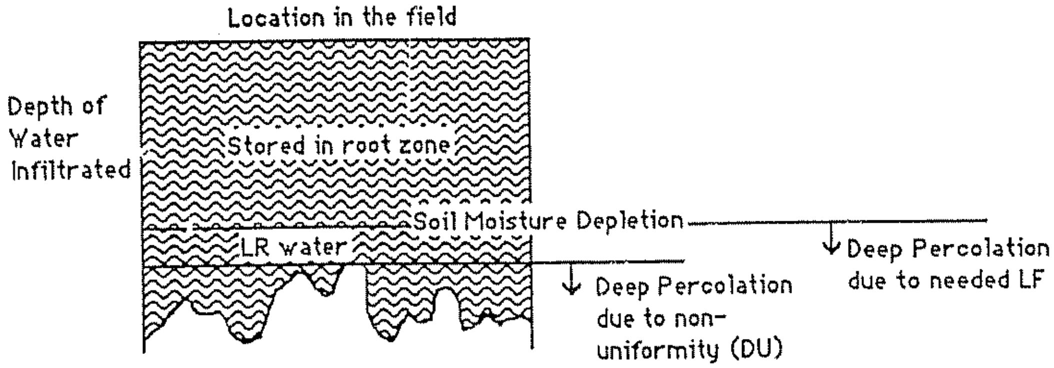

Figure 2. Deep percolation due to LR, LF, and DU. This is a case of "perfect timing" of irrigation, in which enough water has infiltrated at the "driest" point in the field to prevent salt build-up there. LF (Leaching Fraction) accounts for all actual deep percolation, not just the LR.

b. <u>Tailwater runoff</u>. Some tailwater runoff is considered reasonable at present because of :

1. Unknowns regarding disease transmission through recycled tailwater
2. High costs associated with installation of tailwater return systems.
3. Questions regarding proper management of water and labor with tailwater return systems.
4. Questions regarding the importance of tailwater runoff to removing salt which has been deposited on the soil surface through evaporation.
5. Unknowns regarding the need to dilute tile drain water before it goes into the Salton Sea.

Future costs and answers to unknowns will determine the "reasonableness" of tailwater runoff in 10-20 years.

Salinity - General

The primary salinity effects on soils and crops are:

1. Leaf burn (due to high irrigation water salinity, EC_W, sprinkled on leaves).
2. Poor germination or emergence of seedlings (due to high soil salinity, EC_e, in the seedbed).
3. Stunted or reduced yields caused by high root zone salinity, EC_e, after germination/emergence). [*LR deals only with this aspect*].
4. Stunted or reduced yields due to specific ion root toxicity (eg., boron, lithium).
5. Soil structure/aeration/water infiltration problems due to a high percentage of sodium in the soil.

For each problem, researchers have tried to develop:

1. Quantitative relationships between the degree of problem and crop yields.
2. Methods of predicting the degree of the problem (eg., average root zone EC_e) based upon irrigation water quality and various irrigation management schemes.

The almost infinite combinations of crops, varieties of crop, temperatures, soils, irrigation water qualities, irrigation practices, and other cultural practices have frustrated attempts to define (a) and (b).

The amount of extra water which is needed as deep percolation for adequate salt leaching in Imperial Valley is not precisely known, and there have been vastly different estimates regarding the need. Differences occur partly because good salinity research in the U.S. did not begin until the 1950's, and much of that work has been done under conditions different from those in Imperial Valley. Special Imperial Valley conditions include:

1. High temperatures.
2. Cracking clay soils, in which much of the irrigation infiltration into the soil is lateral (from the cracks) rather than vertical (from the soil surface).
3. High concentrations of calcium in the irrigation water.
4. Very low infiltration rates.
5. Artificial drainage (eg., tile drains).
6. Significant preferential flow of water during infiltration.
7. Possible significant contribution of tailwater runoff to maintaining a desirable salt balance.

Root Zone Salinity and Crop Yield

Plants can withstand soil salinity up to some "threshold" level without any decrease in yield. Yields decline linearly as the soil salinity increases beyond the threshold level.

Published crop salt tolerance threshold values are fairly consistent throughout U.S. literature. A major question remains regarding the proper use those values to predict the needed Leaching Requirement (LR). EC_e values (saturated paste extract salinity, in dS/m) for some crops are given in Table 1.

Table 1. Salt tolerances (conventional) for selected crops (Rhoades and Loveday 1990).

Crop	Threshold ECe	% Yield Decline/(dS/m)
Alfalfa	2.0	7.3
Lettuce	1.3	13
Onion	1.2	16
Sudangrass	2.8	4.3
Tomato	2.5	9.9
Wheat (semi-dwarf)	8.6	3.0

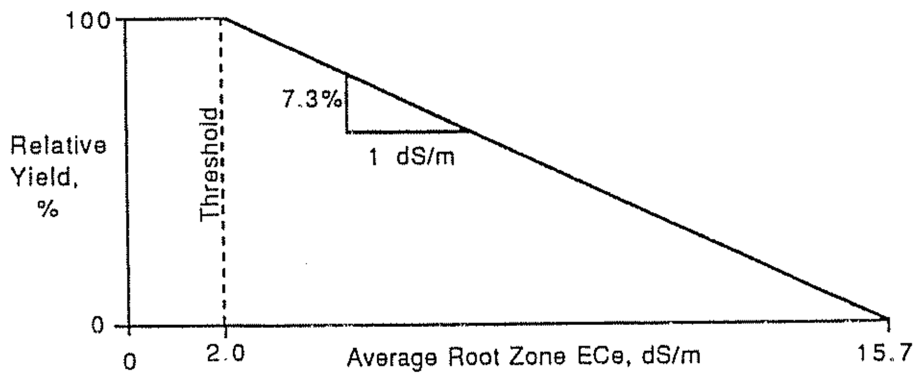

Figure 3. Yield versus soil salinity for alfalfa.

Most threshold EC_e values were developed with research using an artificially salinized soil, with a high leaching fraction to produce a uniform soil salinity with depth. The air/water temperatures in the salinity research were generally lower than summer temperatures in IID. Results of salinity research are affected by irrigation frequency; very frequent irrigations will keep soil salts more dilute than will infrequent irrigations.

In the field, salt concentrations will theoretically tend to increase at the bottom of the root zone due to downward leaching of salts during irrigation. The salinity in the upper portion of the root zone will theoretically be influenced mostly by irrigation water quality; the lower root zone salinity will be influenced more by the size of the LR. There may also be a high salinity at the soil surface in some conditions. Unfortunately for planners in IID, this theoretical salt distribution does not appear to apply to cracking soils as well as to typical sandy, loam, and silt loam soils.

A variety of researchers have tried to predict crop response to root zone salinity distribution. They are summarized in Table 2.

Table 2. Research regarding root zone salinity and yield.

Researcher	Conclusion regarding yield response
Bower et al. (1969)	Average root zone salinity, regardless of the salinity profile shape (crop - alfalfa)
van Schilfgaarde et al. (1974)	As long as roots have access to water of low salinity they are able to utilize some water of high salinity without adverse effects.
Ingvalson et al. (1976)	Average profile root zone salinity (alfalfa)
Rhoades (1983)	Linear average of root zone salinity (conventional irrigation management)
	Weighted salinity for water uptake location (high frequency irrigation management)

The conclusions by Rhoades (1983) appear to have the greatest agreement with actual field studies.

Leaching Requirement (LR)

<u>Definition of LR</u>.

The Leaching Requirement (LR) is the fraction of infiltrated water which must pass through the root zone (and become deep percolation) to maintain some desirable root zone salinity level.

LR values may vary from .01 to .40, depending upon the crop, irrigation water quality, irrigation frequency, soil type, and climate. As will be explained below, the calculation of the LR value is not an exact science. The "LR" value is used in computations to determine the amount of water which must infiltrate at a point:

$$\text{Infiltration needed} = \frac{\text{Soil Moisture Depletion}}{(1 - LR)}$$

<u>Definition of LF</u>

The Leaching Fraction (LF) is the portion of the infiltrated water which <u>actually</u> deep percolates below the root zone. Many, if not most, discussions of leaching assume that irrigation is uniform (ie, DU = 100%), and therefore the assumption is that LF = LR. Actually, the LR is the fraction of infiltrated water which must infiltrate at the point in the field which receives the least amount of water (see Figure 1). In order to determine the water requirement for a whole field, the <u>LF</u> must include water necessary for LR, plus water for non-uniformity (Burt, 1990; Stegman et al., 1981). The minimum LF required on a field is:

$$LF = 1 - [(DU/100)(1-LR)]$$

where DU = Distribution Uniformity of field irrigation, %

The gross irrigation water needed (neglecting evaporation and tailwater runoff) is:

$$\text{Gross needed} = \frac{\text{Net required}}{1 - LF}$$

For questions of required irrigation water, LF should be considered rather than LR.

Conventional Equations for LR.

Since the 1950's, there have been a variety of formulas used to predict the necessary LR. The "conventional" solutions share the following assumptions:

1. There is no chemical precipitation in the root zone.
2. There is no soil contribution from fertilizers.
3. There is no salt contribution from soil weathering.
4. There is no water uptake from a high water table.
5. The soil wets in a classic fashion during an irrigation; that is, a distinct wetting front moves down from the soil surface.

In the Imperial Valley, there can be crop water uptake from a high water table, and the cracking clay soils do not have a classic wetting front during an irrigation. There is also a question about chemical precipitation. Therefore, the classical LR formulas (in Table 3) may not apply in some of the soils within IID.

Table 3. Classical LR formulas from the literature.

Formula (LR =)	Important values	Source
EC_w/EC_{dw}	EC_{dw} = (EC_e at 50% yield reduction) (uniform salinity profile. UP)	Bernstein (1964)
	25% of LR predicted by Bernstein (1964) for low-mod salt tolerance, UP	Bernstein & Francois (1973)
	40% of LR predicted by Bernstein (1964) for salt tolerant crops, UP	Bernstein & Francois (1973)
	EC_{dw} = 2 x (EC_e at 100% yield reduction) (non-uniform profile , NUP)	van Schilfgaarde et al (1974)
	$EC_{dw} = 5\ EC_e - EC_w$ where EC_e is value at 0 % yield decline NUP; logic based on average soil water salinity	Rhoades (1974)
	EC_{dw} = EC_e at 100% yield decline, UP	Ayers (1977)
	EC_{dw} = EC_e of a uniformily salinized root zone w/ 50% crop yield reduction	Bouwer and Idelovitch (1987)
Other	LR depends upon ECw and irrig. frequency	Rhoades and Loveday (1990)

	Leaching Req (LR)	
ECe(threshold)/ECw	High Freq.	Low Freq
1.0	23	.32
1.25	.13	.22
1.5	08	.17
1.75	05	.12
2.0	.03	.10

Formula (LR =)	Important values	Source
	LR depends upon ECw & linearly-averaged, mean root zone salinity. Shown in the Fig. 4	Hoffman (1985)

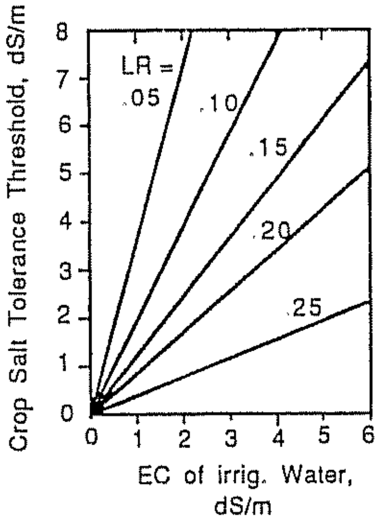

Figure 4. Solution for predicting LR based upon EC_W (Hoffman, 1985)

Hoffman (1985) examined field data from several locations, including Imperial Valley (Lonkerd et al, 1979). He then compared the "experimental measured leaching requirement" in those trials which was necessary for no yield reduction, versus the predicted results using various equations. His comparison is shown in the following figure.

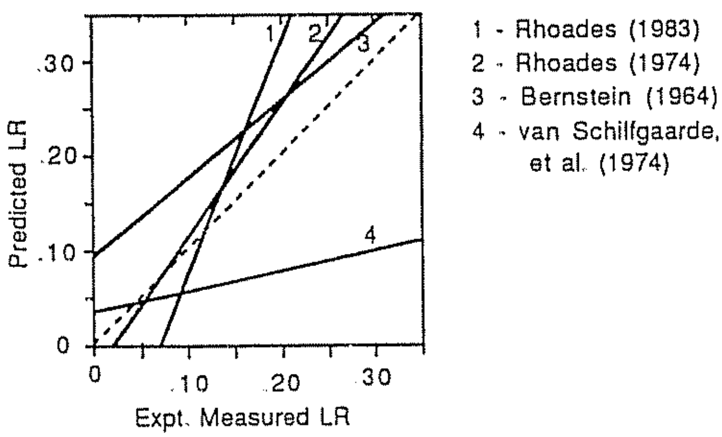

Figure 5. Comparison of LR equations by Hoffman (1985)

The obvious conclusion is that none of the equations precisely predict the limited field results. Furthermore, since each field experiment will provide somewhat different results, it is difficult to know which equation is closest to the "truth". It appears that the equation by Rhoades (1974) most closely matches the field conditions, and may be the most applicable to IID conditions.

Salt Precipitation and LF - Chemical modeling

Much of the work on salt tolerance of crops and LR has been done with chloride salts, which were fairly soluble. The question regarding precipitation arises with high concentrations of calcium in the irrigation water, and the possible formation of lime ($CaCO_3$) or gypsum ($CaSO_4$).

Since the mid 1970's, some researchers have questioned the assumptions that (1) salt precipitation in the soil, and (2) that soil weathering contributions to salinity, are negligible. These assumptions are of primary importance to irrigation management, and to estimates of "conservable water", in the Imperial Valley.

Bliesner, et al. (1977) used irrigation water with EC's ranging from 1.0 - 2.8 in the Ashley Valley in Utah. The water had high levels of calcium salts. Even with no leaching, there was almost no increase in soil salinity during their experiments. Ingvalson, et al. (1976) referred to earlier work which (1) had defined "effective salinity" as salinity in excess of the $Ca(HCO_3)_2$ and $CaSO_4$ in the water, and (2) had considered "effective" soil salinity as only consisting of concentrations of ($Cl + 0.5 \times SO_4$). Oster and Tanji (1985) concluded that the amount of precipitation depends upon the Leaching Fraction (LF) and that with a small (LF), up to half of the salts found in Colorado River water would precipitate out in the soil. [*note: this forms the basis for the Bower (1988?) comments, Exhibit 18*]. The conclusions of Oster and Tanji are based upon chemical models in computer programs. Figure 6 shows their results.

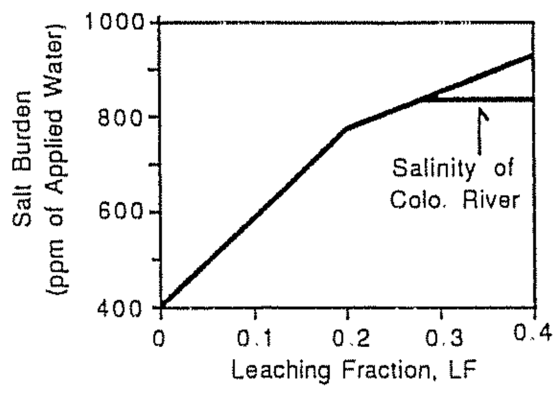

Figure 6. Salt burden of drain water as a function of LR (Oster and Tanji, 1985).

Table 4. Max. EC_e values theoretical possible in IID soils, based upon modeling work of Oster and Tanji (1985), as shown in Figure 6.

LF	Salt Burden[1)]	Ratio SB/830[2)]	ECdw/ECw Ratio/LF[3)]	(ECe at bottom of root zone) ECe/ECw (assumes ECe = .5ECdw)
.05	510	.61	12.3	6.1
.10	590	.71	7.1	3.6
.20	780	.94	4.7	2.3

Notes:

1) The Salt Burden is determined from Figure 6, assuming Colorado River water for irrigation. The value depends upon the leaching fraction, LF.
2) The Ratio is the theoretical ratio of deep percolated salt compared to infiltrated salt. A ratio of 0.61 indicates that only 61% of the salt will deep percolate; 39% of the salt coming in with the irrigation water will precipitate out in the root zone.
3) The (Ratio/LF) is the theoretical relative concentration factor of the drainage water EC, as compared to the irrigation water EC. A value of 12.3 indicates that the drainage water would have 12.3 times greater EC than the irrigation water

Rhoades (1986) also concluded that there is significant salt precipitation in soils irrigated with Colorado River water. Furthermore, he states that "...for an irrigation water of 1 dS/m electrical conductivity, leaching fractions of .022 to .067 would be needed for the most salt-tolerant and sensitive crops, respectively."

Salt Precipitation and LF - Field Work in IID Compared to Theory

Some field studies in Imperial Valley support the idea that salt precipitation may occur between the soil surface and the tile drains. Kaddah and Rhoades (1976) and Grismer (1990) showed that flows into the Salton Sea have a lower percentage of calcium than do flows into IID. Kaddah and Rhoades (1976) concluded, however, "... that the effluent salinity reflects the ground water salinity more than the root zone salinity." Furthermore, they stated that "...salt balance as now evaluated is not a generally meaningful criterion on which to base the adequacy of leaching and salinity control of large irrigation projects."

There is strong field evidence in the Imperial Valley that the theoretical models (eg., Oster and Tanji, 1985) do not adequately explain the salt balance within the root zone in IID. As an example, Table 5, showing soil salinity from the Tailwater Recovery Demonstration fields (IID, 1990) can be examined.

Table 5. Maximum EC_e values from 24" or deeper in the soil (max. depth = 60"). Values taken from four Tailwater Recovery Demonstration fields in IID (IID, 1990).

	Close to drain			Midway between drains			
Field #	1985	1988	1990	1985	1988	1990	
1 North	9.1	5.0	6.4	8.7	3.9	4.8	
1 South	7.6	5.6	5.4	8.1	5.0	5.1	
2 North	16.1	10.7	11.1	15.2	8.8	9.6	
2 South	13.9	14.1	16.7	13.0	13.5	15.5	
3 North	9.3	10.1	10.6	8.4	9.2	9.0	
3 South	7.8	7.9	10.0	7.7	8.3	10.0	
4 East	3.9	3.8	2.3	5.3	3.4	2.6	
4 West	2.0	1.3	1.7	6.4	2.4	4.0	
averages:	8.7	7.3	8.0	9.1	6.8	7.6	(7.9 ave)

The data from Table 5 is useful in examining the applicability of the theory proposed by Oster and Tanji (1985), and arguments submitted by Rhoades (1986). Their argument is that the salinity in the soil root zone will not get dangerously high (for plants) because as the salinity increases, the salts will precipitate out, thereby preventing the soil salinity from rising to a very high level. As mentioned earlier, Rhoades (1986) proposes LF's of .022 - .067 for the most salt tolerant and sensitive crops, respectively.

The Tailwater Demonstration study shows an average maximum soil salinity of 7.9 dS/m in 4 fields. Other studies (Lehman et al, 1968; Hagemann and Ehlig, 1980, van der Tak and Grismer, 1987) have shown numbers in this range in production fields within IID. If these field were typical of IID fields, the LF is 0.15 (representing 15% of the infiltrated water, which is about 10% of the Drop 1 discharges). The work of Oster and Tanji (1985) predicts that with a LF of 0.15, the maximum ECe would be about 2.8 dS/m, rather than the 7.9 dS/m measured.

The "basic" LF formula of

LF = ECw/ECdw

assumes no precipitation of salts, and was not developed for cracking clay soil conditions. Using that equation with an ECw of 1.2 dS/m, and an average LF of 0.15, the maximum ECe can be estimated as follows:

ECdw = 1.2/.15
= 8.0 dS/m

Assuming that the maximum ECe = 0.5 x ECdw
max. ECe = 4.0 dS/m

This value of 4.0 dS/m is higher than the 2.8 dS/m predicted by Tanji and Oster's procedures, but it still does not match the average (of maximum ECe's) of 7.9 dS/m shown in Table 5.

Possible conclusions could be:

1. The actual LR needed is about twice that which is predicted by the "classical" LR methods. This could be explained by the fact that much of the drainage water never passes through the root zone soil, but enters cracks and passes immediately down to the soil below the root zone.

and/or

2. The average LF in the 4 tailwater fields was considerably less than 0.15.

The weak link in the discussion above is the lack of large amounts of field data on soil salinity. Extensive soil salinity data needs to be collected through many fields in order to lay this issue to rest. The thoroughness of data collection within each single field must include ample horizontal and vertical sampling to account for both (a) non-uniformity of water infiltration throughout the field (due to different opportunity times) and (b) the apparent horizontal movement of water from the cracks into the soil.

If insufficient data is collected, there is the tendency to assume that the values are "typical", even though that may not be the case at all. To better understand salinity and leaching in a field, it is important to know what the "extreme" values are, not just the "average" or "typical" EC values. If the "average salinity" in a field is "just right", that half of the field will have excessively high salinity, with resulting yield decreases.

Initial conclusions regarding LR and LF

1. Equations to predict the proper LR vary, are inconsistent, and were not developed to match the IID conditions.
2. Estimates of salt precipitation within the crop root zone appear to be high.
3. **More soil root zone ECe data must be collected, along with measurements of LF, to better evaluate the LR prediction equations. .
4. It is essential to deal with LF (which includes non-uniformity) rather than LR.

High Temperature/Salinity Relationships

General

Insufficient research to determine "threshold ECe" values for crops has been conducted under the extremely hot conditions which are typical of Imperial Valley summers. Discussions of LR within IID have used salt tolerance values obtained in more moderate climates. Crops in the Imperial Valley will suffer salt stress/damage at lower soil salinities than in other areas because of the high temperatures, so current calculations of LR should be modified accordingly. Unfortunately, no one knows precisely how to adjust of salt tolerance data for high temperatures.

Research Results

Several workers have noted the general relationship between high temperatures and increased salinity stress. Braun and Khan (1976) noted with lettuce seed germination that "high temperature and salinity appear to accentuate each other's effects. Thus, salinity, low osmotic potential, water deficit, and other soil related stresses may not be readily evident at low temperatures but may find expression at high temperatures." Elsheikh and Wood (1989) noted a definite correlation between high temperature and salinity damage to chickpea and soybean crops. Hampson and Simpson (1989a, b) studied early growth of wheat and determined that temperature stress on wheat germination showed no effect in the absence of salinity. However, high salinity levels showed a large effect when temperatures were high. There was also a definite interaction with salinity and high temperatures during early seedling growth. Guggenheim and Waisel (1977) noted that Rhodes grass yields dramatically dropped with high temperatures, but it was not clear how to separate the salinity and temperature effects.

Maas and Hoffman (1977) noted that "many crops seem less salt-tolerant when grown under hot dry conditions than under cool humid ones". They quoted earlier research which noted salt-temperature interactions with alfalfa, bean, beet, carrot, cotton, onion, squash, tomato, clover, and salt grass crops.

There is little quantitative, transferrable information in the research. Francois and Goodin (1972) studied sugar beet germination and stated that "when the temperature exceeds 25 C, an approximate 3 dS/m decrease in salinity must accompany each 5 C increase in temperature to prevent reduction in germination damage." They also noted that sugar beets germinated at 25-35 C had about half the germination rate as at 10-15 C, with about 3 dS/m salinity. At 10-15 C, there was almost no effect on germination due to increased salinity. In the Imperial Valley, soil temperatures are in the 40 C range during sugar beet planting time.

Summary of Temperature/Salinity Interactions Research

1. It is well established that crop sensitivity to salinity increases as temperatures increase.
2. It is not clear how to properly adjust the "threshold ECe" values for salinity sensitivity of crops, to compensate for high temperatures.

Yield, ET,and Salt Sensitivity of Alfalfa

General

Alfalfa is a major crop within IID. Factors which affect the ET rate of alfalfa have an important impact upon IID water requirements. Therefore, this section will review some pertinent information regarding alfalfa and water within IID.

General Yield/ET Functions of Alfalfa

Most researchers have determined that alfalfa yield increases linearly as ET increases. Some of the yield functions which have been developed are shown in Table 6.

Table 6. Yield Functions for Alfalfa

Yield = -3.73 + .12 ET	(Yield = tons/ha; ET = cm)	(Donavan and Meek. 1983)
WUE = -1.73 - .041 ET	(Water Use Eff = tons/acre-6 inches of water; ET = inches of water)	(Guitjens, 1982)
WUE = 18.25 kg/ha-mm		(Bolger and Matches, 1990)
Y = - 833 - 159 ET	(Y = kg/ha x 1000; ET = cm/yr)	(Heichel, 1983)
20% under-irrigation of alfalfa = 30% yield decline *Note - this was from a field study in Imperial Valley, and may indicate the relationship between salinity effects and soil dryness		(Oster, et al., 1986)

These yield functions are important because it is generally understood that <u>if yields decline due to salinity, the ET also declines</u> (Hanks, et al., 1977). The same relationship occurs if yields decline due to scald or drainage problems.

Most studies of alfalfa yield have assumed that since it is a vegetative crop, there are no critical growth stages. However, Halim et al (1989) note that stress at bud or flower stages results in disproportionate deterioration of total herbage forage quality. Other researchers have noticed that alfalfa is very sensitive to both dryness and excess water immediately after cutting (Sheaffer et al, 1988). That poses a problem for IID growers with flood irrigation because it is difficult to irrigate without also saturating the soil. Row alfalfa may alleviate part of the saturation problem.

Waterlogging/Scald of Alfalfa

Alfalfa is notorious for its susceptibility to excess soil water (Heichel, 1983). Lehman, et al. (1968) noted that in Imperial Valley, 36 hours of saturation can kill alfalfa. Meek, et al. (1986) observed that top growth of alfalfa can be reduced by 50% when plants are flooded for 2 days at 32 C. Root damage in the same research was only 1% in a clay loam soil compared to 10% in a silty clay soil. Barta (1988), working with mild temperatures, noted that non-clipped alfalfa plants could withstand flooding of up to 14 days without damage.

As with salinity tolerances, different cultivars of alfalfa have different sensitivities to waterlogging. The cultivar Salton is considered tolerant to adverse waterlogging during high temperatures (Donovan and Meek, 1983).

The exact physiological cause of alfalfa damage from waterlogging has been debated. Heichel (1983) states that it is due to anoxia (lack of oxygen) and impaired mineral absorption by the roots. Sheaffer et al. (1988) state that damage is due to the lack of oxygen in the root zone and the formation of ethanol and other toxic substances in the roots. They state that the effects of phytophthora root rot are secondary. Meek et al. (1986) felt that oxygen deficiency, not ethylene toxicity, seemed to be the problem when alfalfa was flooded. Barta (1988) found that cultivars highly resistant to phytophthora root rot are generally more resistant to flooding injury.

High Water Table Effects on Alfalfa Yield

Rai et al. (1971) found that alfalfa yields are dramatically affected (decreases of 61%) if the water table rises immediately after harvest. This has important implications for IID irrigation practices.

Salinity Effects on Alfalfa (most research done at "normal" temperatures)

Ingvalson et al. (1976) determined that average profile soil salinity is a useful index of salinity for relating alfalfa yield response under conditions of flood irrigation management. Bower et al. (1969) also found that alfalfa yield was high related to average root zone salinity, regardless of the salinity profile shape. Bernstein and Francois (1973) believed that alfalfa responded more to calculated mean salinity against which the water was absorbed than to soil water salinity averaged by depth.

Ingvalson et al. (1976) determined the equivalent "threshold EC_e" would be about 1.7 dS/m - 2.4 dS/m, depending upon the moisture level in the soil. They also noted that alfalfa roots may become more sensitive to salinity with age. The most commonly quoted "threshold EC_e" for alfalfa is 2.0 dS/m (Rhoades and Loveday, 1990; Maas and Hoffman, 1977). Hoffman et al. (1975) found a "threshold EC_e" of about 1.7 dS/m in studies with average daytime temperatures of 28 C (considerably lower than IID summer temperatures).

Various alfalfa cultivars have different sensitivities to salinity. Ashraf et al. (1987) indicated that there is a good potential to breed new cultivars of alfalfa for improved salt tolerance.

It has been noted that alfalfa seedlings, as with most crops, can suffer great damage if the seedbed is salty and dry (Assadian and Miyamoto, 1987). Heichel (1983) states that germination is practically inhibited at soil moisture tensions (including matrix and osmotic potentials) of -12 to -15 bars.

Robinson (1980) examined leaf burn problems with sprinkler irrigation of alfalfa in the Imperial Valley. He found that application rates of greater than 5 mm/hr greatly compacted the soil, but that application rates of less than 4.0 mm/hr caused significant leaf burn. Ninety three percent of the plants had leaf burn with an application rate of 1.8 mm/hr, versus 2.5 percent damage at 4.0 mm/hr.

Special Soil Conditions in Imperial Valley

In much of the Imperial Valley, border strip irrigation is actually "irrigation by cracks". The size of the cracks will determine the amount of infiltrated water during an irrigation. van der Tak and Grismer (1987) found that the amount which will infiltrate during a border strip irrigation is almost equivalent to the volume of cracks at that time.

The cracks allow drainage from tile lines to occur almost immediately during/after an irrigation, although the hydraulic conductivity of the soil is not high enough to permit such rapid drainage. This early water drainage is probably not very effective in leaching. van der Tak and Grismer (1987) conclude that "traditional design concepts of....leaching fraction.....have limited meaning in the context of heavily cracking soils due to crack dominance of water flow through the soil... However, depending upon the average crack depth, irrigation water may not adequately....leach, the root zone."

Adequate leaching of alfalfa fields is so difficult on some Imperial Valley soils that farmers must depend on leaching which occurs while growing other crops, in order to establish a long-term soil salinity which is low enough to grow the crops.

Work should be conducted on ways to increase the effectiveness of root zone leaching with a given LF. New methods of leaching will be accompanied by new irrigation methods and new ways to cultivate crops. As an example, it is generally understood that sprinklers provide more effective leaching of salts (per unit of water infiltrated) than surface irrigation on most soils. This is because a greater percentage of the infiltrated water moves down through micro-pores rather than macro-pores; crack infiltration is also minimized. Wide adaptation of sprinklers throughout IID would affect water delivery requirements, air quality, irrigation system costs, tailwater management, and labor requirements.

Conclusions and Estimates For the Future

Research clearly shows that some trends do exist and that many current formulas/values are questionable at best. There seem to be two choices:

1. Do not make a decision because it is unclear what "truth" is, even though it seems obvious that the present numbers are probably incorrect, or
2. Make an estimate and depend upon future research to (a) verify the estimates or (b) develop better estimates.

The estimates/predictions/conclusions are:

1. <u>Conventional "threshold ECe" values for crops in IID should be reduced by 25%</u>, to account for the extremely high temperatures. The new "threshold ECe" value for alfalfa should be 1.5 dS/m rather than 2.0 dS/m.
2. <u>The required LR can best be estimated by the equation</u>:

$$LR = \frac{ECw}{5\ ECe - ECw}$$

where ECw = EC of the irrigation water, dS/m
ECe = <u>Threshold ECe of the most sensitive crop to be grown in a rotation on that field</u>. It is based upon the average root zone ECe.

This definition has a powerful conclusion which is not currently accepted - that the leaching requirements in IID should not be calculated based upon the crops currently planted, but rather, on the most sensitive crops to be grown on the fields.

This particular equation of LR (from Rhoades, 1974) was not developed for the majority of IID soils. The key assumptions which make it incorrect are:

a. Preferential flow of water through cracks is ignored (ie, it underestimates the LR needed).
b. Salt precipitation in the root zone is ingored (ie, it overestimates the LR needed).

The net result may be that it is approximately correct.

3. LF requirements should assume DU values ranging from 90% - 75% (clay - sand). This is higher than in most areas of California, but corresponds to the unique sealing properties of some Imperial Valley soils and the fact that surface irrigation is used.
4. Evapotranspiration requirements will increase by 5 - 10% as farming practices/drainage/salt control improves. This does not account for increases in temperature, and ignores introduction of new short season varieties of crops.
5. A desirable Leaching Fraction (LF) for a heavy clay soil, averaged over several years and crops, is estimated as follows:

LR - Based upon a modified threshold ECe of 1.5 for alfalfa. This assumes that alfalfa has a deeper root zone than the more salt-sensitive crops which will be grown in a rotation. If the average ECe in the root zone is 1.5 for alfalfa, it may be 1 - 1.3 for shallower rooted crops in the same soil, since they will not be exposed to the deeper, more saline soil profile.
- Assumes that Colo. River water salinity will rise to ECw = 1.4 in 10 years.

$$LR = ECw/(5ECe - ECw)$$
$$= 1.4/([5 \times 1.5] - 1.4) = .23$$

LF - Based upon a DU of 90%

$$LF = 1 - [(DU/100)x(1 - LR)]$$
$$= 1 - [.90 \times (1-.23)]$$
$$= .31$$

Many IID farmers might immediately state that such a high LF would kill their plants because of suffocation; they just cannot get that much extra water into the ground for some crops. The responses to this could be:

a. Perhaps that is true.
b. Perhaps, when one considers the total crop rotation plan, it may be possible to have a higher LF than presently obtained.
c. These computations do not state what is currently happening - they point to what may be realistic future needs, when crop mixes may be different and new irrigation/cultivation techniques may enhance leaching abilities.

Recommendations for Future Research

1. More data is needed to correlate LF with soil ECe. This would involve extensive 3-dimensional soil sampling, and probably include ECsw estimates made with surface salinity sensors. New research should be conducted on representative soils within IID, and probably will require a research plot design in which the LF can be carefully measured in each treatment.
2. Better information is needed for the relationship between salt sensitivity and temperatures.
3. Research should better define what constitutes the "root zone depth" for various crops grown in rotation in IID.
4. Development of new high yielding, short season crop varieties and more salt- and waterlog-resistant alfalfa cultivars should be encouraged.
5. Work needs to be done on improving the efficiency of the LF through different cultural or irrigation methods.

References

Ashraf, M., T. McNeilly, and A.D. Bradshaw. 1987. Selection and Heritability of Tolerance to Sodium Chloride in Four Forage Species. Crop Sci. 227: 232-234.

Assadian, N. W. and S. Miyamoto. 1987. Salt Effects on Alfalfa Seedling Emergence. Agron. Journal 79: 710-714.

Ayers, R. S. 1977. Quality of Water for Irrigation. Journal of I&D Engineering, ASCE. 103(2): 135-154.

Barta, A. L. 1988. Response of Field Grown Alfalfa to Root Waterlogging and Shoot Removal. I. Plant Injury and Carbohydrate and Mineral Content of Roots. Agron. Journal 80: 889-892.

Bernstein, L. 1964. Salt Tolerance of Plants. U.S. Dept. of Agr. Information Bull. No. 283. Washington, D.C.

Bernstein, L. and L. E. Francois. 1973. Leaching Requirement Studies: Sensitivityof Alfalfa to Salinity of Irrigation and Drainge Waters. Soil Science Soc. Amer. Proc. 37: 931-943.

Bliesner, R. D., R. J. Hanks, L. G. King, and L. S. Willardson. 1977. Effects of Irrigation Management on the Quality of Irrigation Return Flow in Ashley Valley, Utah. Soil Sci. Soc. of Am. Journal. 41: 424-428.

Bolger, T.P. and A. G. Matches. 1990. Water-Use Efficiency and Yield of Sainfoin and Alfalfa. Crop Sci. 30: 143-148.

Bouwer, H. and E. Idelovitch. 1987. Quality Requirements for Irrigation with Sewage Water. Journal of I&D Engineering, ASCE. 113(4):516-535.

Bower, C.A. 1988?. Reasonable Water Requirements for Irrigation, IID and CVWD: Salinity Control and Irrigation Efficiency Aspects. Exhibit 18.

Bower, C.A., G. Ogata, and J.M. Tucker. 1969. Rootzone Salt Profiles and Alfalfa Growth as Influenced by Irrigation Water Salinity and Leaching Fraction. Agron. Journal 61:783-785.

Braun, J.W. and A.A. Khan. 1976. Alleviation of Salinity and High Temperature Stress by Plant Growth Regulators Permeated into Lettuce Seeds via Acetone. J. Amer. Soc. Hort Sci. 101(6): 716-721.

Burt, C. M. 1990. Efficiency in Irrigation. Presentation to Water District managers at Pardee Reservoir. Oct. 18.

Donovan, T.J. and B.D. Meek. 1983. Alfalfa Responses to Irrigation Treatment and Environment. Agron. Journal 75: 461-464.

Elsheikh, E.A. and M. Wood. 1989. Response of Chickpea and Soybean Rhizobia to Salt: Influence of Carbon Source, Temperature and pH. Soil Biol. Biochem. 21(7): 883-887.

Francois, L. E., and J.R. Goodin. 1972. Interaction of Temperature and Salinity on Sugar Beet Germination. Agron. Journal 64: 272-273.

Grismer, M.E. 1990. Leaching Fraction, Soil Salinity, and Drainage Efficiency. California Agriculture 44(6): 24-26.

Grismer, M.E. 1986. Irrigation, Drainage and Soil Salinity in Cracking Soils. In the UC Coop. Extension "Soil and Water", Fall 1986, No. 68.

Guggenheim, J. and Y. Waisel. 1977. Effects of Salinity, Temperature and Nitrogen Fertilization on Growth and Composition of Rhodes Grass. Plant and Soil 47: 431-440.

Guitjens, J. C. 1982. Models of Alfalfa Yield and Evapotranspiration. Journal of I&D Engineering, ASCE. 108(3): 212-222.

Hagemann, R.W. and C. F. Ehlig. 1980. Sprinkler Irrigation Raises Yields - And Costs - of Imperial Valley Alfalfa. California Agriculture. January. pp 8-9.

Halim, R. A., D. R. Buxton, M. J. Hattendorf, and R. E. Carlson. 1989. Water-Deficit Effects on Alfalfa at Various Growth Stages. Agron. Journal 81: 765-770.

Hampson, C.R. and G. M. Simpson. 1989a. Effects of Temperature, Salt, and Osmotic Potential on Early Growth of Wheat. I. Germination. Can. J. Bot. 68: 524-528.

Hampson, C.R. and G. M. Simpson. 1989b. Effects of Temperature, Salt, and Osmotic Potential on Early Growth of Wheat. II. Early Seedling Growth. Can. J. Bot. 68: 529-532.

Hanks, R.J. , T.E. Sullivan, and V.E. Hunsaker. 1977. Corn and Alfalfa Production as Influenced by Irrigation and Salinity. Soil Sci. Soc. of Am. Journal 41: 606-610.

Heichel, G.H., 1983. Alfalfa. Chapter 4 in Crop-Water Relations. , Teare and Peet (ed.). Wiley and Sons, N.Y. pp 127-155.

Hermsmeier. L.F.. 1978. Drainage Practice in Imperial Valley. Transactions of the ASAE. 21: 105-108.

Hoffman, G. J. 1985. Drainage Required to Manage Salinity. Journal of I&D Engineering, ASCE. 111(3): 199-206.

Hoffman, G. J., E.V. Maas, and S.L. Rawlins. 1975. Salinity-Ozone Interactive Effects on Alfalfa Yield and Water Relations. J. Environ. Qual. 4(3):326-331.

IID, 1990. Tailwater Recovery Demonstration Program Study, Special Technical Report, Sept. by Boyle Engr.

Ingvalson, R.D., J.D. Rhoades, and A.L. Page. 1976. Correlation of Alfalfa Yield with Various Index of Salinity. Soil Science 122(3): 145-153.

Kaddah, M.T. and J.D. Rhoades. 1976. Salt and Water Balance in Imperial Valley, California. Soil Sci. Soc. Am. J. 40:93.

Lehman, W. F., S. J. Richards, D. C. Erwin, and A. W. Marsh. 1968. Effect of Irrigation Treatments on Alfalfa (Medicago Sativa L.) Production, Persistence, and Soil Salinity in Southern California. Hilgardia 39(9): 277-295.

Lonkerd, W. E., C. F. Ehlig, and T. J. Donovan. 1979. Salinity Profiles and Leaching Fractions for Slowly Permeable Irrigated Field Soils. Soil Sci. Soc. Am. J. 43:287-289.

Maas, E.V., and G.J. Hoffman. 1977. Crop Salt Tolerance - Current Assessment. Journal of I&D Engineering, ASCE. 103(2): 115-134.

Meek, B. D., T. J. Donovan, and L. E. Graham. 1986. Alfalfa Stand Losses From Irrigation: Influence of Soil Temperature, Texture, and Aeration Status. Soil Sci. Soc. Am. J. 50: 651-655.

Oster, J. D., J. L. Meyer, L. Hermsmeier, and M. Kaddah. 1986. Field Studies of Irrigation Efficiency in the Imperial Valley. Hilgardia 54(7): 1-15.

Oster, J.D. and K.K. Tanji. 1985. Chemical Reactions Within Root Zone of Arid Zone Soils. Journal of I&D Engineering, ASCE. 111(3): 207-216.

Rai, S.D., D.A. Miller, and C.N. Hittle. 1971. Response of Alfalfa Varieties to Different Water Table Depths at Various Stages of Growth. Agron. Journal 63:331-332.

Rhoades, J.D. 1974. Drainage for Salinity Control. Chap. 16 in Drainage for Agriculture. Agronomy Monograph 17. Amer. Soc. of Agronomy. Madison, WI.

Rhoades, J.D. 1983. Reclamation and Management of Salt-Affected Soils After Drainage. From Irrig. Assoc. Short Course on Surface Irrigation, held in Phoenix.

Rhoades, J.D. 1986. Salt Problems From Increased Irrigation Efficiency. Journal of I&D Engineering, ASCE. 111(3): 218 - 229.

Rhoades, J.D. and J. Loveday. 1990. Salinity in Irrigated Agriculture. Chap. 36 in Irrigation of Agricultural Crops. Agronomy Monograph 30. Amer. Soc. of Agronomy. Madison, WI.

Robinson, F. 1980. Irrigation Rates Critical in Imperial Valley Alfalfa. California Agriculture. October. p. 18.

Sheaffer, C.C., C.B. Tanner, and M.B. Kirkham. 1988. Alfalfa Water Relations and Irrigation. Chap. 11 in Alfalfa and Alfalfa Improvement. Agronomy Monograph 29. Amer. Soc. of Agronomy. Madison, WI.

Stegman, E.C., J.T. Musick, J.I. Stewart. 1981. Irrigation Water Management, Chap 18 in Design and Operation of Farm Irrigation Systems. M. Jensen (ed). Amer. Soc. of Agric. Engr. St. Joseph, MI.

van der Tak, L.D., and M.E. Grismer. 1987. Irrigation, Drainage, and Soil Salinity in Cracking Soils. Transactions of the ASAE 30(3): 740-744.

van Schilfgaarde, J., L. Bernstein, J. Rhoades, and S. L. Rawlins. 1974. Irrigation Management for Salt Control. Journal of I&D Engineering, ASCE. 100(3): 321-338.